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Abundance of White-tailed Deer (*Odocoileus virginianus*) within Valley Forge National Historical Park and Movements Related to Surrounding Private Lands

Technical Report NPS/NERCHAL/NRTR-03/091

ON THE COVER
White-tailed deer at Valley Forge National Historical Park.
Photograph by Gino D'Angelo.

Abundance of White-Tailed Deer (*Odocoileus virginianus*) within Valley Forge National Historical Park and Movements Related to Surrounding Private Lands

Technical Report NPS/NERCHAL/NRTR-03/091

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NPS D-59 February 2003

Table of Contents

Page

List of Figures v

List of Tables vii

Executive Summary xi

Acknowledgments xv

Introduction 1

Study Area 3

Methods 5

Capture and Marking 5

Deer Survey Compartments 6

Vehicle-based Deer Counts 9

Radio-telemetry Monitoring 11

Home Range Estimation 13

Analyses of Cover-Type Selection 14

Results 17

Capture and Marking 17

Vehicle-based Deer Counts 17

Home Range Analyses 26

Home Ranges and the Park Boundary 37

Movements Relative to the Park Boundary 38

Habitat Composition of Home Ranges 40

Cover-Type Use Within the Park 45

Table of Contents (continued)

Page

Cover-Type Use Outside the Park 54

Landscape Use 54

Mortalities 60

Discussion 65

Conclusions 71

Literature Cited 73

Appendix 79

List of Figures

Page

Figure 1. Aerial photograph of Valley Forge National Historical Park, Pennsylvania and surrounding private land, 1997 4

Figure 2. Boundaries of compartments at Valley Forge National Historical Park and surrounding private land used to conduct vehicle-based white-tailed deer counts at dusk during April through May 1997, 1998, and 1999. Aerial photograph taken in 1997 7

Figure 3. Distribution of fixed telemetry stations used to collect directional data on radio-equipped white-tailed deer within Valley Forge National Historical Park and surrounding private lands during 1997, 1998, and 1999 12

Figure 4. Habitat composition of white-tailed deer count compartments within Valley Forge National Historical Park and surrounding private lands, 1997 15

Figure 5. Driving routes for annual monitoring of white-tailed deer abundance within Valley Forge National Historical Park 28

Figure 6. Annual sampling intensity versus home range area for white-tailed deer captured, marked, and monitored in Valley Forge National Historical Park and surrounding lands during 1997, 1998, and 1999 34

Figure 7. Percentage of female white-tailed deer radio locations outside the park relative to the Valley Forge National Historical Park boundary during 1997, 1998, and 1999 combined 39

Figure 8. Use versus availability of cover types by female white-tailed deer that had greater than 50% home range area within Valley Forge National Historical Park during 1997, 1998, and 1999 47

Figure 9. Diel use of meadow and forest cover types by female white-tailed deer that had greater than 50% home range area within Valley Forge National Historical Park during 1997, 1998, and 1999 combined 49

Figure 10. Use versus availability of cover types by male white-tailed deer that had greater than 50% home range area within Valley Forge National Historical Park during 1997, 1998, and 1999 51

List of Figures (continued)

Page

Figure 11. Diel use of meadow and forest cover types by male white-tailed deer that had greater than 50% home range area within Valley Forge National Historical Park during 1997, 1998, and 1999 combined 53

Figure 12. Landscape use by radio-marked white-tailed deer that had greater than 50% home range area within Valley Forge National Historical Park composited over 1997, 1998, and 1999 56

Figure 13. Landscape use by radio-marked white-tailed deer that had greater than 50% home range area within Valley Forge National Historical Park, 1997 57

Figure 14. Landscape use by radio-marked white-tailed deer that had greater than 50% home range area within Valley Forge National Historical Park, 1998 58

Figure 15. Landscape use by radio-marked white-tailed deer that had greater than 50% home range area within Valley Forge National Historical Park, 1999 59

List of Tables

Page

Table 1. Cover type composition (%) of white-tailed deer count compartments within and around Valley Forge National Historical Park, 1997 8

Table 2. Cover type composition (%) of the portion of white-tailed deer count compartments within Valley Forge National Historical Park, 1997 8

Table 3. Cover type composition (%) of the portion of white-tailed deer count compartments outside the boundary of Valley Forge National Historical Park, 1997 10

Table 4. White-tailed deer captured and marked within Valley Forge National Historical Park and surrounding private lands during 1997 18

Table 5. White-tailed deer captured and marked within Valley Forge National Historical Park and surrounding private lands during 1998 19

Table 6. White-tailed deer captured and marked within Valley Forge National Historical Park and surrounding private lands during 1999 21

Table 7. Observed number of all white-tailed deer (Obs.) and those marked (Mark) within Valley Forge National Historical Park during vehicle-based counts conducted at dusk during 1997 22

Table 8. Observed number of all white-tailed deer (Obs.) and those marked (Mark) within Valley Forge National Historical Park during vehicle-based counts conducted at dusk during 1998 22

Table 9. Observed number of all white-tailed deer (Obs.) and those marked (Mark) within Valley Forge National Historical Park during vehicle-based counts conducted at dusk during 1999 22

Table 10. White-tailed deer population estimates within Valley Forge National Historical Park during 1997, 1998, and 1999 23

Table 11. Mean number of white-tailed deer counted during three replicate surveys within the portion of each of six compartments within Valley Forge National Historical Park during 1997, 1998, and 1999 25

List of Tables (continued)

Page

Table 12. Number of white-tailed deer, including those marked (in parentheses), observed within compartments outside of Valley Forge National Historical Park during vehicle-based counts conducted at dusk during 1997, 1998, and 1999 27

Table 13. Annual home range (ha) estimates (95% adaptive kernel and 100% minimum convex polygon) for white-tailed deer within Valley Forge National Historical Park and surrounding private lands during 1997 29

Table 14. Annual home range (ha) estimates (95% adaptive kernel and 100% minimum convex polygon) for white-tailed deer within Valley Forge National Historical Park and surrounding private lands during 1998 30

Table 15. Annual home range (ha) estimates (95% adaptive kernel and 100% minimum convex polygon) for white-tailed deer within Valley Forge National Historical Park and surrounding private lands during 1999 32

Table 16. Mean annual home range (ha) estimates (95% adaptive kernel and 100% minimum convex polygon) for adult and juvenile (< 1 year old) white-tailed deer monitored within Valley Forge National Historical Park and surrounding private lands during 1997, 1998, and 1999 35

Table 17. Pearson correlation coefficients (r) of white-tailed deer home range estimates (100% minimum convex polygon vs. 95% adaptive kernel) within Valley Forge National Historical Park and surrounding private lands during 1997, 1998, and 1999 36

Table 18. Percent cover-type composition of female white-tailed deer home ranges (100% minimum convex polygon estimates) within Valley Forge National Historical Park and surrounding private lands during 1997, 1998, and 1999 41

Table 19. Percent cover-type composition of home range area for female white-tailed deer that had greater than 50% home range area within Valley Forge National Historical Park and those that had greater than 50% home range area outside the park boundary during 1997, 1998, and 1999 43

List of Tables (continued)

Page

Table 20. Percent cover-type composition of male white-tailed deer home ranges (100% minimum convex polygon estimates) within Valley Forge National Historical Park and surrounding private lands during 1997, 1998, and 1999 44

Table 21. Percent cover-type composition of home range area for male white-tailed deer that had greater than 50% home range area within Valley Forge National Historical Park and those that had greater than 50% home range area outside the park boundary during 1997, 1998, and 1999 46

Table 22. Availability and use of cover types by female white-tailed deer that had greater than 50% home range area within Valley Forge National Historical Park during 1997, 1998, and 1999 48

Table 23. Availability and use of cover types by male white-tailed deer that had greater than 50% home range area within Valley Forge National Historical Park during 1997, 1998, and 1999 52

Table 24. Availability and use of cover types by white-tailed deer that had greater than 50% home range area within Valley Forge National Historical Park during 1997, 1998, and 1999 combined 52

Table 25. Availability and use of cover types by white-tailed deer that had greater than 50% home range area on private lands adjacent to Valley Forge National Historical Park during 1997, 1998, and 1999 combined 55

Table 26. Availability and use of cover types by female white-tailed deer that had greater than 50% home range area on private lands outside the boundary of Valley Forge National Historical Park during 1997, 1998, and 1999 55

Table 27. Mortalities of marked white-tailed deer recorded within Valley Forge National Historical Park and surrounding private lands during 1997, 1998, and 1999 61

Table 28. Cause-specific mortality of marked white-tailed deer within Valley Forge National Historical Park and surrounding private lands during 1997, 1998, and 1999 62

List of Tables (continued)

Page

Table 29. Cause-specific mortality (n) of the annual sample of marked (N) white-tailed deer within Valley Forge National Historical Park and surrounding private lands during 1997, 1998, and 1999 64

Table 30. Mortality (n) observed each year from each annual sample of marked white-tailed deer within Valley Forge National Historical Park and surrounding private lands during 1997, 1998, and 1999 64

Table 31. Cause-specific mortality (n) of available marked white-tailed deer (N) that were captured within Valley Forge National Historical Park (Park) and surrounding private lands (Private) during 1997, 1998, and 1999 64

Executive Summary

In the metropolitan and suburban landscape of southeastern Pennsylvania, the abundance of white-tailed deer (*Odocoileus virginianus*) is of considerable public interest and debate. The population of white-tailed deer at Valley Forge National Historical Park (VAFO) is perhaps the most well known regional example. To provide information for the planning and management of VAFO, a study of white-tailed deer within the park and adjacent suburban lands was conducted during 1997, 1998, and 1999. Objectives were to determine 1) the abundance of deer within the current (1997) park boundary, 2) the home range and movements of deer inside the park and on adjacent land, and 3) the type of vegetative cover used more or less than expected by deer at various times.

A complete census of all individuals in a large free-roaming deer population is not feasible, therefore, a mark-resight technique was employed to estimate the number of white-tailed deer within the park. One hundred twenty deer were captured and marked during the three years. Ninety-four females and 19 males were equipped with radio-collars or ear-tag transmitters. Seven females wore vinyl collars with no transmitter attached. In 1997, 45 deer were captured and marked, 36 within the park and 9 on private land. Fifty-five deer were captured and marked in 1998, 37 within the park and 18 on private land. And in 1999, 20 deer were captured and marked, 12 within the park and 8 on private land.

Eight geographic sampling units, called compartments, were defined and used to count deer. A sighting index was derived from the ratio of marked individuals seen to the number of marked individuals known from radio telemetry to be in the area. Using the sighting index, a population estimate of deer within the park was computed. Population estimates could not be computed for adjacent lands primarily because buildings hindered the sighting of deer. Deer were counted three times in April-May of each year of the three-year study. The mean of these counts was 557 deer in 1997, 536 in 1998, and 577 in 1999. When the sighting index was applied, estimates of the deer population in the park were 772 in 1997, 913 in 1998, and 1,016 in 1999. The mean annual density was 70/km^2 (181 deer/mile^2).

Annual home ranges for 90 females and 15 males were determined. Individual locations of deer were determined using a hand-held or vehicle-based telemetry unit that received a signal from transmitters on deer collars and ear tags. The 100% minimum convex polygon and the 95% adaptive kernel home range estimators were used to determine annual home ranges. Most annual home ranges were less than 200 hectares (498 acres), with the largest being those of juvenile males. Average female annual home range area was 100.7 hectares (249 acres), based on the minimum convex polygon method.

Average distance traveled beyond the park boundary was 122 meters (401 feet) for the 71 females that had greater than 50% home range within the park. The maximum distance that one of these females traveled beyond the park boundary was 1,094 meters (3,589 feet). Locational data for males were limited because of the small number equipped with radio transmitters. Of 15 annual home ranges calculated for males, 13 were almost completely inside the park (98%-100%). The remaining two annual home ranges were greater than 50% outside the park.

Vegetative cover preferred by monitored deer was investigated. Average forest cover within home ranges of females was 49, 43, and 43% for 1997, 1998, and 1999, respectively. Home range meadow cover averaged 37, 41, and 41%, respectively, for those same years. The remaining cover was residential and agricultural. Home ranges of males averaged 54, 52, and 51% forest cover and 28, 31, and 25% meadow cover, respectively, for the three years. Both males and females spent more time in meadows during the night and in forest cover during the day.

Spatial distribution, or landscape use, of deer that had greater than 50% of their home range within the park indicated high use in the central and southwestern portion of the park. In the southwestern corner of the park, daily movements of deer occurred primarily from the area of Stirling's Headquarters to the residential neighborhood to the west, where deer would spend the night. In the western portion of the park, south of the river, deer moved infrequently between the park and private property. North of the river in the northwestern section of the park there was nocturnal movement of deer into the adjacent residential area. Deer that occupied the area adjacent to the agricultural fields

of Saint Gabriel's Hall foraged in and around those fields at night and spent the day in the park woodlot. There was little or no movement of deer into the mobile home development on the northeastern boundary of the park. In the southeastern portion of the park there was movement of deer into the Glen Hardie neighborhood at night. The Pennsylvania turnpike is a significant barrier to deer along the southern park boundary. However, deer did occasionally cross that highway.

Of the 120 deer that were captured and marked, 39 mortalities were observed. Vehicle collisions were the most common cause of mortality, accounting for 69% (27 of 39) of all mortalities. This result is consistent with previous results from 1984 to 1995 that indicated an average of 78 deer per year killed on park roads. Vehicle-deer collisions accounted for 84% of known deer mortalities during that time.

Earlier studies in Pennsylvania reported deer density at Gettysburg National Military Park increased from 37/km^2 (95/mile^2) to 53/km^2 (136/mile^2) during 1990-93, and deer density averaged 58/km^2 (150 deer/mile^2) during 1992-94 at Letterkenny Army Depot near Chambersburg. The PA Game Commission reported that Pennsylvania supported 1.5 million white-tailed deer at an average density of 12.8/km^2 (33.2 deer/mile^2) state-wide in 2000. For comparison, estimates of white-tailed deer numbers in VAFO increased from 772 to 1,106 from 1997 to 1999, an average annual density of 70 deer/km^2 (181 deer/mi^2). Continued growth of the deer herd is probable.

Acknowledgments

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Introduction

White-tailed deer (*Odocoileus virginianus*) have increased in abundance in the northeastern U.S. (Warren 1997). Hunting opportunities and recreational viewing have increased with the increase in deer abundance; however, agricultural and ornamental plant damage, forest regeneration complaints, and deer-vehicle collisions also have increased. White-tailed deer occur on lands regulated by various political entities. Human-defined regulations and boundaries are not recognized by white-tailed deer. Hunting has been the traditional deer management tool, however, in parks and urban-suburban areas, deer hunting is often not permitted. Valley Forge National Historical Park (VAFO) is situated in an urban-suburban landscape (USDI 1982). In 1984, using aerial surveys and pellet counts, Cypher et al. (1985) estimated a range of 165-185 white-tailed deer inhabited the 1,250 ha VAFO study area that included the southern portion of the Schwoebel nursery (21 ha), the Consolidated Rail Corporation (Conrail) right-of-way (21 ha), and the Washington Memorial Chapel grounds (16.8 ha). Standardized spotlight counts have been used to index deer abundance in VAFO, and from 1986 to 1995, the spotlight index increased from 98 to 437, a 446% increase (Heister 1996). Between 1984 and 1995, an average of 78 deer/year were killed on roads within VAFO. Vehicle-deer collisions accounted for 84% of known deer mortalities during that time period. Deer hunting is not permitted in VAFO and only archery hunting is permitted on portions of the surrounding area. Many landowners do not permit trespass to hunt. White-tailed deer abundance on public lands and their impact on public natural resources have been documented (McShea et al. 1997). A related problem, white-tailed deer impact on adjacent landowners' resources, has received less attention. There is anecdotal evidence that white-tailed deer may forage in a public park and fulfill other life requisites outside the park, and vice-versa. We estimated the abundance of white-tailed deer in VAFO and documented movements of white-tailed deer between the park and surrounding landscape, which is urban and suburban development composed primarily of small (<0.25 ha) private properties.

Study Area

Valley Forge National Historical Park is located on the Coastal Plain/Piedmont Uplands 20 km northwest of Philadelphia, PA. The 12.95 km^2 (5 $mile^2$) park, primarily forest (50.2%) and meadows (40.2%), is located on the border of Chester and Montgomery counties, Pennsylvania, an area of commercial development and residential areas (Figure 1). VAFO boundary spatial data were provided by the National Park Service GIS Technical Support Center at North Carolina State University. This boundary and resulting area were used throughout the project, including data analysis. After we had completed all analyses and the first draft of this report, we were informed that updated spatial boundary data were available. It was decided not to redo the maps and analyses because of the effort and minimal effects on the results. Therefore, there is a discrepancy in the boundary and the area (approximately 103 ha less) of the park used in this report versus those used in other recent documents. All estimates that we computed are correct, based on the boundaries, and hence area, that we were provided.

Bowersox and Larrick (1999) characterized the forested area of the park as containing 30 tree and 6 shrub species. The dominant tree species were yellow poplar (*Liriodendron tulipifera)* and oaks (*Quercus* spp.), with spice bush (*Lindera benzoin*), viburnum (*Viburnum* spp.), and dogwood (*Cornus* spp.) in the understory. Meadow coverage was characterized as grasses (65%), vines (20%), forbs (10%), bare ground (4%), and woody and sedge (<1%). Dominant species were Japanese honeysuckle (*Lonicera japonica*) (18.7%), red panic grass (*Panicum agrostides)* (18.6%), tall purple top (*Triodia flava*) (9.6%), red fescue (*Festuca rubra*) (7.5%), and sweet vernal grass (*Anthoxanthum odoratum*) (6.5%) (Heister, K. – Pers. commun.). Summaries of the climate, history, vegetation, and adjacent land uses are provided by Cypher et al. (1985), Heister et al. (2000), and USDI (1982).

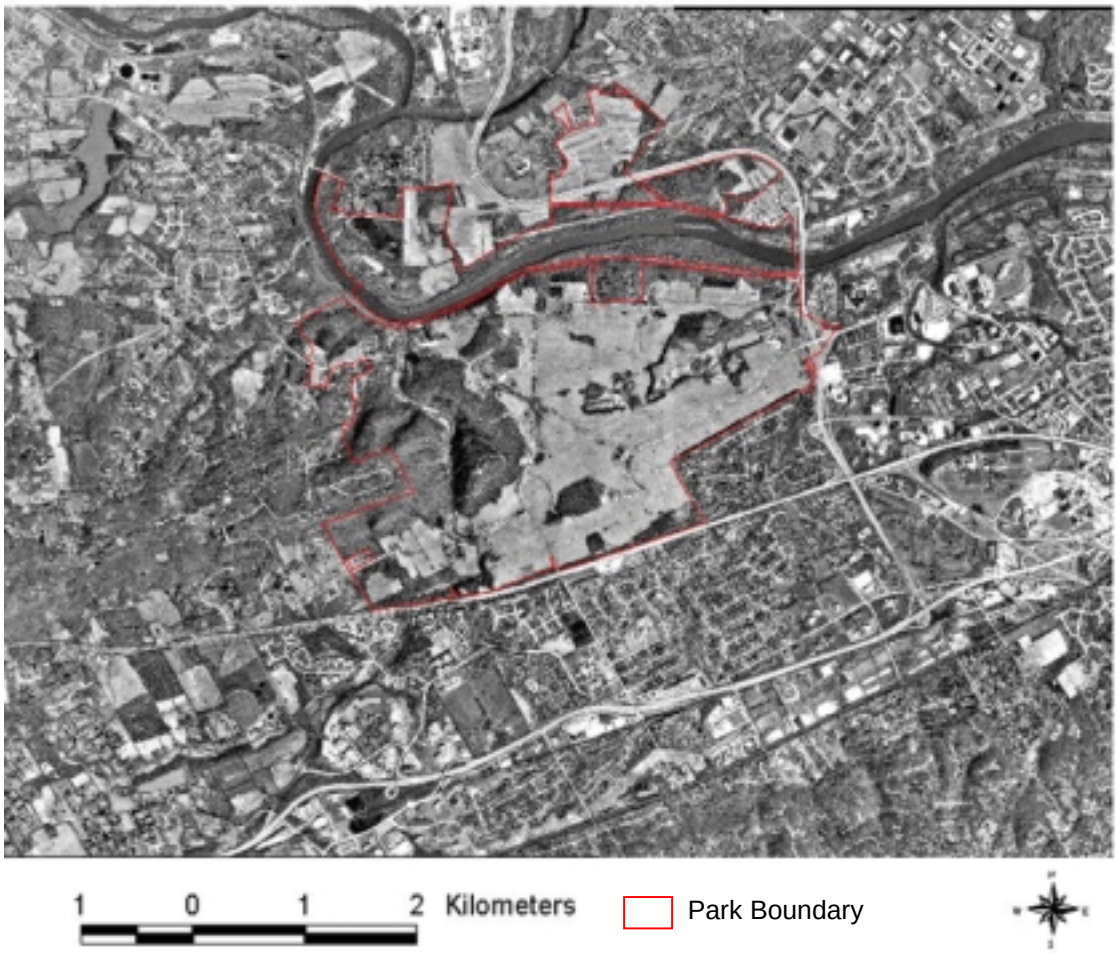

Figure 1. Aerial photograph of Valley Forge National Historical Park, Pennsylvania and surrounding private land, 1997.

Methods

Capture and Marking

To estimate abundance, we used the mark-resight approach, which necessitated the capture and marking of deer. White-tailed deer were captured (The Pennsylvania State University, Institutional Animal Care and Use committee Permit No. 96R082B1) within VAFO and surrounding private lands, $\leq$ 3 km from the park boundary, using tranquilizer guns and immobilization agents. Deer were immobilized with an intramuscular injection of ketamine hydrochloride and xylazine hydrochloride. We used an initial dosage of 5 mg/kg of ketamine hydrochloride and 2 mg/kg of xylazine hydrochloride to capture deer during 1997, but these dosages were later increased to 6 mg/kg ketamine hydrochloride and 3 mg/kg xylazine hydrochloride during 1998 and 1999 to reduce induction times. Immobilizing agents were purchased and stored in powdered form and mixed at facilities provided by The Pennsylvania State University 3 to 5 days prior to use. At VAFO, immobilizing agents were stored in a secure (locked and alarmed) facility and were loaded into darts usually less than one hour prior to darting.

We used tranquilizer guns (Pneu-Dart Inc., Williamsport, PA) equipped with laser sighting devices and radio-telemetry equipped transmitter darts (Advanced Telemetry Systems (ATS) Isanti, MN) to deliver immobilizing agents. The majority of darting was performed from vehicles during twilight and night periods during January through April of 1997, 1998, and 1999. Deer capture efforts usually involved crews of 2 to 4 trained personnel. Deer were darted from a distance of < 30m, because efficiency was greatly reduced at greater distances. Hand-held spotlights were used to locate deer prior to darting and to assist with shot placement at the primary target, the rump.

After dart delivery, we waited 20 minutes prior to exiting the vehicle and attempting to locate the immobilized deer. If visual contact with the deer was lost, a portable receiver and a 2-element yagi antenna were used to locate the transmitter-equipped dart (Kilpatrick et al. 1996). Dart transmitters were at a frequency of 151 MHz. Once a

darted deer was located, a lone crew member approached it, placed a mask over the deer's eyes, and if necessary, restrained the deer until other crew members were able to assist with handling. The dart was removed and any resulting minor wound was treated with Betadine® solution. Deer were ear-tagged with color-coded and numbered ear-tags and the sex and estimated age were determined. Seven of 33 adult females were fitted with vinyl-only collars in 1997. With the exception of one adult female equipped with an ear-tag transmitter in 1998, all other adult females were equipped with radio-collars (164-165MHz) (ATS, Inc, Isanti, MN). Seven juvenile deer captured during 1997, and 13 adult males captured during the three years were also equipped with ear-tag transmitters (164-165MHz) (ATS, Inc, Isanti, MN). At approximately 45 minutes post-induction, the effects of xylazine were reversed using yohimbine hydrochloride (Wallingford et al. 1996). During 1997, we injected yohimbine hydrochloride (5mg/ml) in the hindquarter. During subsequent field seasons, yohimbine hydrochloride (5mg/ml) was injected intravenously at the dorsal surface of the ear. We monitored recovery of each animal and observed each deer until it walked or ran from the processing site. Tagged deer were subsequently checked 4 to 8 hours post-handling to insure complete and safe recovery from marking procedures.

Deer Survey Compartments

Eight compartments were established as geographic sampling units for vehicle-based spring deer counts (Figure 2). Compartments varied in area from 198 to 326 ha (Table 1). Compartment boundaries were based on roads, streams, forest boundaries, and topography and were designed to minimize deer movement among compartments during counts.

Compartments 2 and 3 comprised the central core region of the park; these compartments were characterized by small woodlots (4-17 ha) interspersed among meadow (Table 2). Meadows comprised from 9 to 52% of compartments primarily within the park, whereas forest cover-types (deciduous forest, developed forest, and

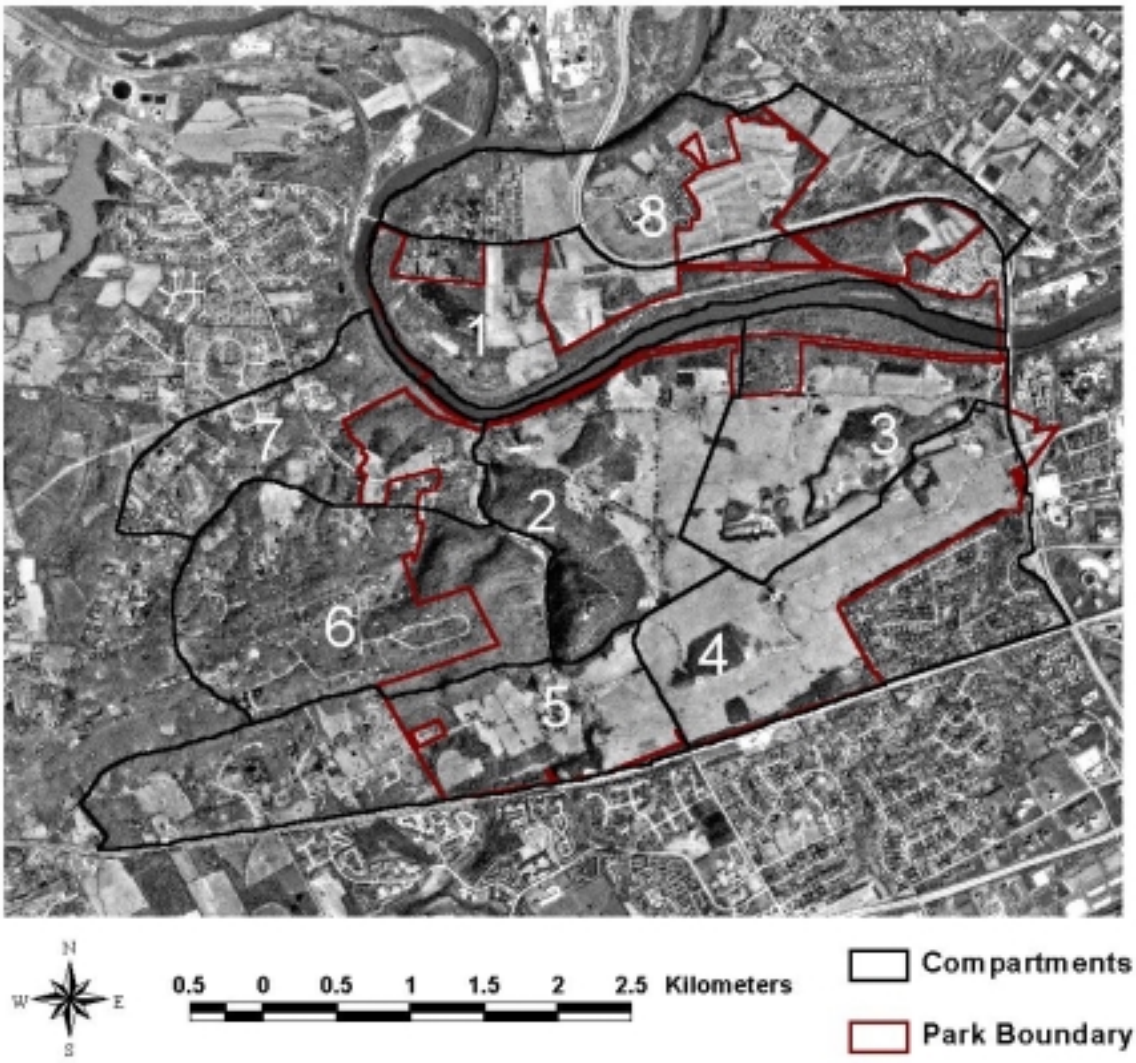

Figure 2. Boundaries of compartments at Valley Forge National Historical Park and surrounding private land used to conduct vehicle-based white-tailed deer counts at dusk during April through May 1997, 1998, and 1999. Aerial photograph taken in 1997.

Table 1. Cover type composition (%) of white-tailed deer count compartments within and around Valley Forge National Historical Park, 1997.

	Compartment							
Cover type	1 (284 ha)	2 (243 ha)	3 (241 ha)	4 (326 ha)	5 (299 ha)	6 (306 ha)	7 (198 ha)	8 (277 ha)
Deciduous forest	60.8	53.7	42.5	13.0	30.5	23.5	40.0	25.9
Developed forest	0.0	0.0	0.0	0.0	24.6	71.0	13.8	5.8
Conifer forest	2.8	3.3	4.8	1.1	0.6	0.0	1.3	0.3
Meadow	8.6	39.4	52.3	52.4	24.8	0.0	0.0	0.0
Field	2.6	3.0	0.1	0.3	11.4	5.4	11.7	6.5
Maintained lawn	5.4	0.0	0.0	2.2	2.0	0.0	0.0	7.8
Agriculture	12.4	0.0	0.0	0.0	0.0	0.0	0.0	36.4
Unvegetated	0.0	0.6	0.1	0.4	0.0	0.0	0.0	0.0
Residential	7.0	0.0	0.0	30.5	6.1	0.1	33.0	16.9
Water	0.3	0.0	0.1	0.0	0.0	0.0	0.2	0.2

Table 2. Cover type composition (%) of the portion of white-tailed deer count compartments within Valley Forge National Historical Park, 1997.

	Compartment							
Cover type	1 (196 ha)	2 (235 ha)	3 (219 ha)	4 (224 ha)	5 (136 ha)	6 (75 ha)	7 (54 ha)	8 (58 ha)
Deciduous forest	71.6	52.5	38.1	18.4	47.3	95.4	56.0	15.0
Developed forest	0.0	0.0	0.0	0.0	0.0	2.9	12.7	0.0
Conifer forest	4.0	3.3	5.2	1.5	0.0	0.0	3.1	0.0
Meadow	12.3	40.5	56.5	74.6	52.7	0.0	0.0	0.0
Field	3.2	3.1	0.1	0.5	0.0	1.7	27.8	0.8
Maintained lawn	4.2	0.0	0.0	3.2	0.0	0.0	0.0	8.7
Agriculture	4.1	0.0	0.0	0.0	0.0	0.0	0.0	73.9
Unvegetated	0.0	0.6	0.0	0.6	0.0	0.0	0.0	0.0
Residential	0.3	0.0	0.0	1.2	0.0	0.0	0.0	1.6
Water	0.3	0.0	0.1	0.0	0.0	0.0	0.4	0.0

conifer forest) comprised from 14 to 63% of the compartments. Compartment 5 was primarily forest (deciduous and developed) in its eastern section and contained an interspersion of developed forest areas and the field cover-type in the west. Compartments 7 and 8 were the only compartments that contained active agricultural lands. Compartment 4 contained the least amount of forest cover and included a residential area (31%) in the southeast section. Compartments 1, 5, 7, and 8 also contained residential or developed areas outside the park boundary. Compartments 6 and 7 were dominated by privately owned forest, primarily developed forest areas, west of the park boundary (Table 3).

Vehicle-based Deer Counts

We used vehicle-based deer counts at dusk and mark-resight estimates to estimate deer population size within VAFO (Storm et al. 1992, Thompson et al. 1998). Counts were conducted directly from vehicles using accessible roadways within designated deer count compartments. All available roadways were traversed at least once during each survey period. An observer left the vehicle and traversed a compartment on foot only when terrain features obstructed viewing opportunities from roadways. Three counts were conducted from April through May 1997, 1998, and 1999 during 60-minute survey periods beginning approximately 35 minutes prior to sunset. During 1997, 5 compartments (1-5) were used to coordinate vehicle-based deer counts, whereas an additional 3 compartments (6-8) were designated for the 1998 and 1999 surveys. Compartments (2, 3, and 4) in the southern region of the park were counted simultaneously by multiple observers to prevent duplicate counts if deer traversed from one compartment to another.

Observers used laminated aerial photos (1992 with current ground updates) to record the number of marked and unmarked deer observed on private or park land in each compartment. Only deer equipped with radio-collars or vinyl, non-transmitting collars were counted as marked, due to difficulties in visually detecting ear-tag transmitters. Radio-telemetry monitoring was conducted within 24 hours prior to surveys to assess

Table 3. Cover type composition (%) of the portion of white-tailed deer count compartments outside the boundary of Valley Forge National Historical Park, 1997.

	Compartment							
Cover type	1 (88 ha)	2 (8 ha)	3 (22 ha)	4 (102 ha)	5 (163 ha)	6 (232 ha)	7 (145 ha)	8 (219 ha)
Deciduous forest	36.7	94.9	98.3	0.6	16.4	0.5	34.0	28.9
Developed forest	0.0	0.0	0.0	0.0	45.1	92.8	14.2	7.4
Conifer forest	0.0	2.1	0.0	0.1	1.1	0.0	0.7	0.4
Meadow	8.1	0.0	0.0	0.0	3.7	0.0	0.0	7.6
Field	1.3	0.6	0.0	0.0	21.0	6.5	5.6	8.0
Maintained lawn	0.3	2.4	0.2	1.3	1.5	0.0	0.0	0.0
Agriculture	31.3	0.0	0.0	0.0	0.0	0.0	0.0	26.4
Unvegetated	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0
Residential	22.2	0.0	0.0	98.0	11.1	0.1	45.4	21.0
Water	0.3	0.0	0.0	0.0	0.0	0.0	0.1	0.3

location of and availability of marked deer during subsequent counts. For park land only, a sighting index, expressed as the proportion of the number of marked deer seen to the number of marked deer known to occur, was computed for each count. A sighting index could not be computed for private lands primarily due to the obstructions (mainly buildings) that dominated the landscape.

Observers also recorded group size (number of deer in each group), location, and whether the deer were located in open versus forested areas. This information was used to reference field notes on the laminated photos to count data forms. These procedures were used to avoid replicate counting when several passes were made through a compartment. Deer were recorded as located on either park or private lands, but abundance estimates were computed only from data related to deer within the park.

Radio-telemetry Monitoring

We developed a radio-telemetry monitoring protocol based on a network of 128 fixed-location telemetry stations, points of known geographic position distributed throughout the park and surrounding private lands (Figure 3), to locate radio-equipped deer on a systematic basis (White and Garrott 1990). These fixed locations were determined from known survey locations and with the Global Positioning System, and were identified on aerial photographs. These stations, in various combinations, served as base locations for the radio-locating of deer. Observers used hand-held and vehicle-based (Lovallo et al. 1994) telemetry systems to estimate directional azimuths toward each deer from three to five fixed telemetry stations. A vehicle-based system was used primarily during 1998, whereas hand-held equipment (4-element yagi-type antennae and portable receiver) was used more frequently during 1997 and 1999. Locations were only estimated when all azimuths were collected during a period of less than 25 minutes to minimize effects of deer movement on location accuracy. Lists of deer frequencies were organized into groups by general locations and available vehicle travel routes to optimize the number of deer that could be located from each given subset of fixed stations. Resulting groups were randomly selected to be located during each telemetry

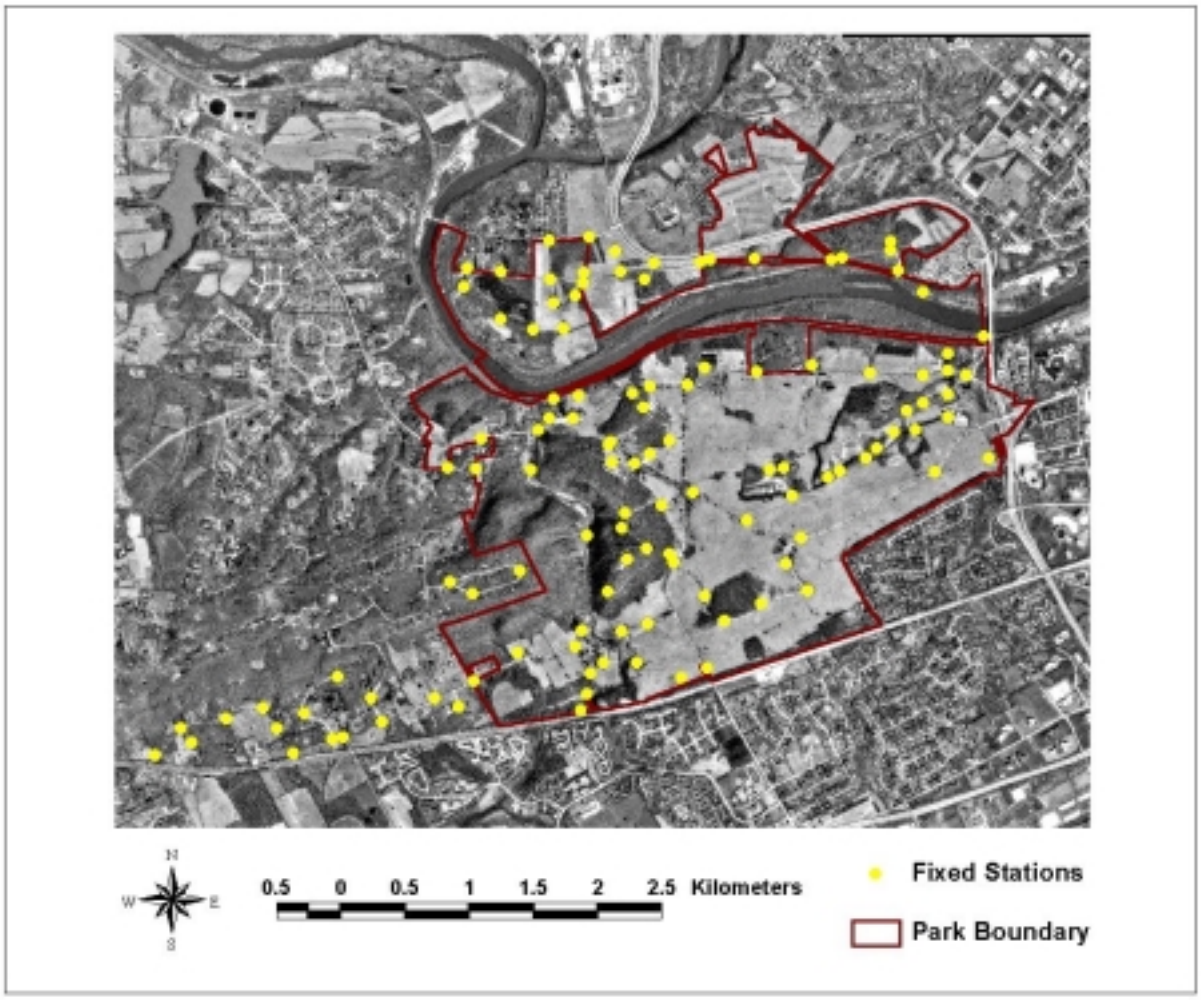

Figure 3. Distribution of fixed telemetry stations used to collect directional data on radio-equipped white-tailed deer with Valley Forge National Historical Park and surrounding private lands during 1997, 1998, and 1999.

session, the period of time required to locate the sample of radio- equipped deer. Telemetry sessions were systematically staggered to sample all diel periods.

Geographic coordinates of radio-collared and radio-tagged deer were estimated from azimuths recorded from the fixed telemetry stations. We used a computer program (LOCATE II, Nams 2000) to calculate the position (Universal Transverse procedure calculated best estimates of deer positions with a standard angular error of 3.0 degrees, based on maximum likelihood method estimators.

Home Range Estimation

We used two independent methods to estimate home range area based on radio-telemetry determined locations. One hundred percent minimum convex polygon estimates (i.e., minimum perimeter method) were constructed to include 100 percent of telemetry- determined locations (Mohr 1947), whereas adaptive kernel estimates were developed to represent 95% utilization of the home range (Worton 1989). One hundred percent minimum convex polygon estimates were used to assess cover-type composition of home ranges. Adaptive kernel estimates were calculated to reduce the influence of outlier observations on estimates of home range size. Both estimates were computed to permit comparison to other published home range estimates. We used the Animal Movement extension with Arcview (ESRI, Redlands, CA) to estimate deer home range size and evaluate habitat use (Hooge and Eichenlaub 1997). Home range area was estimated annually and on a composite (multi-year) basis. Home range area was compared among years and between males and females.

We created landscape utilization distributions (Kernohan et al. 1998) from the composite home ranges. Additionally, we analyzed the radio-telemetry locations as point data. We computed the proportion of locations within the park boundary as an index to utilization.

Analyses of Cover-type Selection

A cover-type map was developed, based on available aerial photography and field reconnaissance within the park and surrounding privately owned lands, to assess cover-type composition and selection by radio-equipped deer (Figure 4). Identified cover types included: deciduous forest, conifer forest, developed forest (primarily deciduous forest interspersed with homes and low density residential developments), fields (herbaceous areas that were not maintained), lawns (herbaceous areas frequently mowed), meadows (herbaceous areas mowed annually), unvegetated areas (paved areas and quarries), residential areas (high density development), and agricultural areas (row crops or grain).

Deer use of cover types within their home range was compared to availability within the park and surrounding areas using Chi-square goodness of fit tests, and Bonferroni 95% confidence intervals were estimated according to Neu et al. (1974). The total area used for cover-type availability was determined by constructing a 100% minimum convex polygon using all deer locations for all years combined. This polygon did not include summer radio-locations of deer “40” due to expansive seasonal migrations (See seasonal migration). Approximately forty-nine percent of this composite multi-year polygon of area was within the boundary of the park and 2,535.9 ha were outside the park. Cover types were considered selected if their use significantly exceeded expectations based on availability and were considered avoided if use was significantly less than expected. Cover-type selection was estimated on annual and composite (multi-year) basis for males and females.

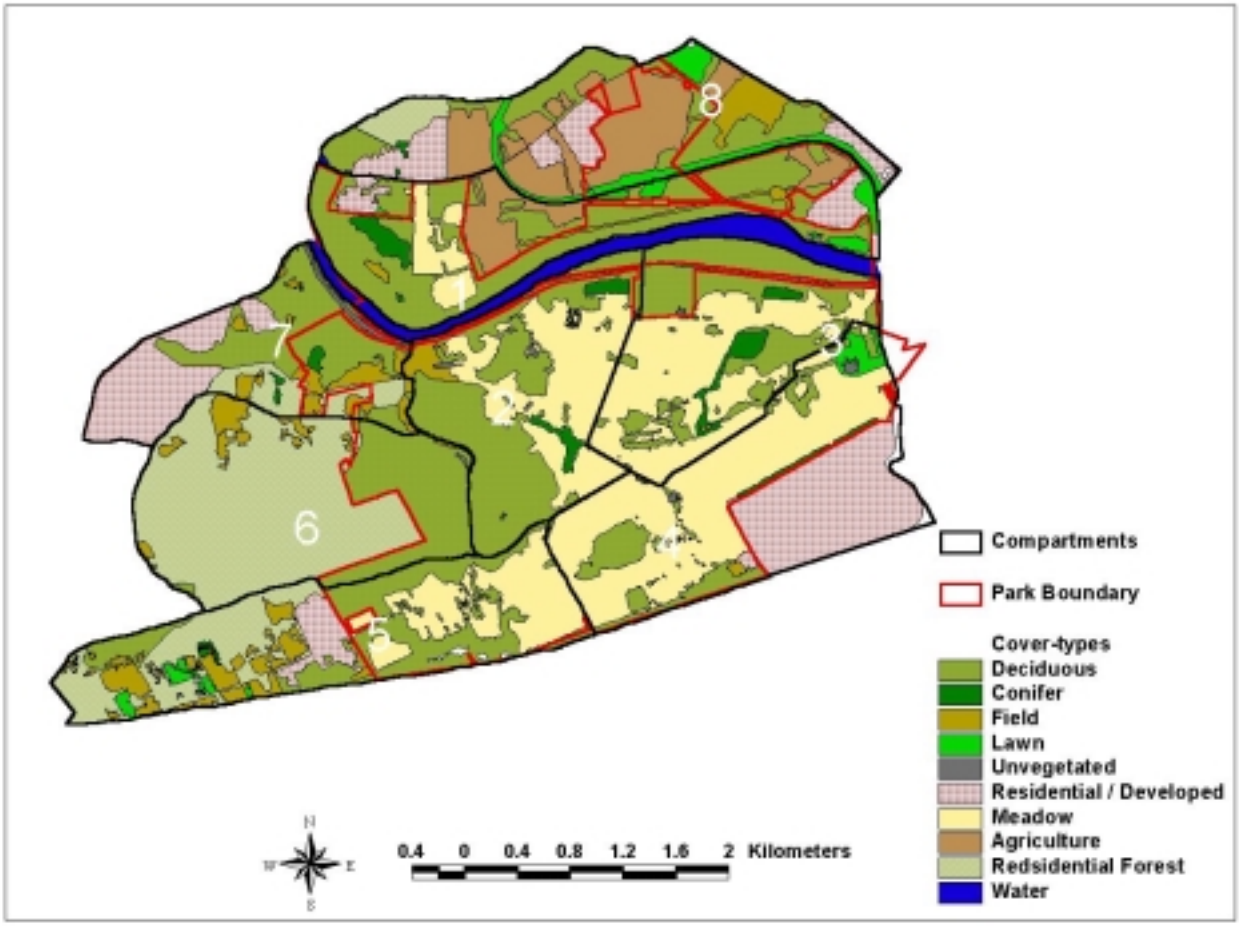

Figure 4. Habitat composition of white-tailed deer count compartments within Valley Forge National Historical Park and surrounding private lands, 1997.

Results

Capture and Marking

A total of 120 deer were captured, marked, and released during January through April of 1997, 1998, and 1999 (Tables 4, 5, and 6). One hundred thirteen deer were equipped with radio-transmitters (collars or ear-tag transmitters). Seven deer were marked with vinyl collars (no transmitter attached) during 1997. Vinyl, non-transmitting collars were used during 1997 to increase sample size for estimation of the 1997 sighting index.

During 1997, we expended 194 tagging team hours (2-4 people) during 29 days to capture and radio-collar 45 deer (37 females, 8 males) within VAFO and surrounding lands. Ten of the deer (4 females, 6 males) captured in 1997 were juveniles (< 1 year old); all deer captured and radio-equipped in subsequent field seasons were adults. In 1998 we expended 254 tagging team hours during 26 days to capture and radio-equip 55 deer (47 females, 8 males). During 1999 we expended 104 tagging team hours during 10 days to capture and radio-equip 20 deer (17 females, 3 males).

Twenty-nine percent (5 males and 30 females) of all deer captured were on private lands surrounding the park. Deer were captured on private lands within five primary areas including: developments along Yellow Springs Rd. (west boundary), the Glen Hardie development (south boundary), developments along Route 23 including Freedom's Foundation property (west boundary), agricultural fields adjacent to Walnut Hill (north boundary), and residential areas along Catfish Lane (north boundary).

Vehicle-based Deer Counts

Mean number of deer counted within the park during three replicate counts averaged 557 in 1997, 536 during 1998, and 577 during 1999 (Tables 7, 8, 9, and 10). Park

Table 4. White-tailed deer captured and marked within Valley Forge National Historical Park and surrounding private lands during 1997.

Deer ID	Capture Date	Frequency[a] (MHz)	Sex	Age	Radio-collar Color(s)	Ear-tag Description[b]				Capture Location
						Left		Right		
						Number	Color	Number	Color	
1	02/12/1997	164.054	Female	Adult	Red	52	Red	53	Red	Park
2	02/13/1997	164.882	Female	Adult	Yellow	57	Red	56	Red	Park
3	02/13/1997	164.366	Male	Adult	None	58	Red	Trans	Yellow	Park
4	02/18/1997	164.985	Female	Adult	Green	55	Red	none	none	Park
5	02/18/1997	164.908	Female	Juvenile	Blue	6	Orange	7	Orange	Park
6	02/18/1997	164.189	Female	Adult	Yellow/Green	2	Orange	3	Orange	Park
7	02/19/1997	164.150	Female	Juvenile	Red/Blue	1	Orange	4	Orange	Private
8	02/19/1997	164.583	Male	Juvenile	None	8	Orange	Trans	Yellow	Park
9	02/19/1997	164.243	Female	Adult	Red/Black	23	Orange	22	Orange	Park
10	02/20/1997	164.951	Female	Adult	Black	24/25	Orange	21	Orange	Park
11	02/20/1997	164.103	Female	Adult	Green/Red	3	White	4	White	Park
12	02/22/1997	164.261	Female	Adult	Blue/Green	1	White	2	White	Park
13	02/23/1997	164.211	Female	Adult	Black/Blue	6	White	5	White	Park
14	02/23/1997	164.090	Female	Adult	Red/Yellow	10	Orange	9	Orange	Park
15	02/23/1997	164.029	Female	Adult	Black/Silver	7	White	8	White	Park
16	02/24/1997	164.276	Female	Adult	Yellow/Black	None	None	12	White	Park
17	02/24/1997	164.243	Female	Adult	Red/Black	9	White	10	White	Park
18	02/25/1997	164.525	Female	Juvenile	None	Trans	Yellow	71	Red	Park
19	02/26/1997	164.014	Female	Juvenile	Black/Green	13	White	14	White	Park
20	02/26/1997	164.545	Male	Juvenile	None	Trans	Yellow	15	White	Park
21	03/04/1997	164.326	Female	Adult	Blue/Silver	16	White	17	White	Park
22	03/04/1997	164.990	Female	Adult	Yellow/Orange	22	White	21	White	Park
23	03/04/1997	164.310	Female	Adult	Silver/Yellow	20	White	19	White	Park
24	03/05/1997	164.563	Male	Juvenile	None	Trans	Yellow	11	White	Park
25	03/05/1997	164.133	Female	Adult	Silver	18	White	23	White	Private
26	03/05/1997	164.828	Female	Adult	Blue/Orange	25	White	24	White	Park
27	03/06/1997	164.504	Male	Juvenile	None	Trans	Yellow	73	Red	Park
28	03/11/1997	164.080	Female	Adult	Brown	75	Red	74	Red	Private
29	03/11/1997	164.230	Female	Adult	Brown	26	Red	27	Red	Park
30	03/10/1997	Vinyl 1	Female	Adult	Yellow	78	Red	79	Red	Park
31	03/12/1997	164.384	Male	Juvenile	None	Trans	Yellow	87	Red	Park
32	03/12/1997	164.168	Female	Adult	Brown	28	Orange	30	Orange	Private
33	03/11/1997	Vinyl 3	Female	Adult	Yellow	90	Orange	91	Orange	Park
34	03/11/1997	Vinyl 2	Female	Adult	Yellow	82	Red	81	Red	Park
35	03/13/1997	164.653	Male	Adult	None	Trans	Yellow	94	Red	Private
36	03/12/1997	Vinyl 4	Female	Adult	Yellow	86/89	Red	88	Red	Private
37	03/14/1997	Vinyl 5	Female	Adult	Yellow	96	Red	99	Red	Park
38	03/19/1997	164.295	Female	Adult	Brown	98	Red	92	Red	Private
39	03/20/1997	164.605	Male	Juvenile	None	95	Red	Trans	Yellow	Park
40	03/20/1997	164.937	Female	Adult	Silver/Yellow	76	Red	77	Red	Park
41	03/20/1997	Vinyl 6	Female	Adult	Yellow	14	Orange	13	Orange	Park
42	03/22/1997	Vinyl 7	Female	Adult	Yellow	85	Red	84	Red	Park
43	03/23/1997	164.118	Female	Adult	Brown	93	Red	80	Red	Private
44	03/24/1997	164.344	Female	Adult	Brown	15	Orange	16	Orange	Private
45	03/24/1997	164.908	Female	Adult	Blue	17	Orange	18	Orange	Park

[a]Vinyl=collar only

[b]Trans=ear-tag radio transmitter

Table 5. White-tailed deer captured and marked within Valley Forge National Historical Park and surrounding private lands during 1998.

Deer ID	Capture Date	Frequency (MHz)	Sex	Age	Radio-collar Color(s)	Eag-tag Description[a] Left Number	Left Color	Right Number	Right Color	Capture Location
46	01/28/1998	165.253	Female	Adult	Brown/Yellow	49	White	28	Red	Park
47	01/29/1998	165.062	Female	Adult	Red/Yellow	26	Red	46	White	Park
48	01/29/1998	165.203	Female	Adult	Red/Green	47	White	27	Red	Private
49	01/31/1998	165.223	Female	Adult	Black	40	Orange	41	Orange	Park
50	01/31/1998	165.264	Female	Adult	Black	29	Red	none	none	Park
51	01/31/1998	164.444	Male	Adult	None	Trans	Yellow	38	Orange	Park
52	01/30/1998	165.123	Female	Adult	Red	50	White	48	White	Park
53	02/01/1998	164.414	Male	Adult	None	45	Orange	Trans	Orange	Park
54	02/06/1998	164.118	Female	Adult	Red/Black	47	Orange	46	Orange	Park
55	02/01/1998	165.533	Female	Adult	Yellow	42	Orange	43	Orange	Private
56	02/07/1998	164.403	Male	Adult	None	Trans	Yellow	37	Orange	Private
57	02/07/1998	165.514	Female	Adult	Green	49	Orange	48	Orange	Private
58	02/07/1998	164.485	Male	Adult	None	105	Red	Trans	Yellow	Park
59	02/07/1998	164.211	Female	Adult	Black/Blue	101	Red	102	Red	Park
60	02/08/1998	165.092	Female	Adult	Brown	115	Red	106	Red	Private
61	02/08/1998	165.023	Female	Adult	Brown	114	Red	113	Red	Park
62	02/09/1998	165.150	Female	Adult	Brown	103	Red	104	Red	Park
63	02/11/1998	165.141	Female	Adult	Yellow	108	Red	107	Red	Park
64	02/11/1998	165.211	Female	Adult	Brown	118	Red	117	Red	Private
65	02/11/1998	164.261	Female	Adult	Blue/Green	111	Red	112	Red	Private
66	02/12/1998	164.445	Male	Adult	None	Trans	Yellow	110	Red	Private
67	02/12/1998	164.384	Female	Adult	None	Trans	Yellow	121	Red	Park
68	02/12/1998	165.352	Female	Adult	Yellow/Black	119	Red	123	Red	Park
69	02/13/1998	165.133	Female	Adult	Brown	124	Red	36	Orange	Park
70	02/13/1998	165.011	Female	Adult	Brown	120	Red	122	Red	Private
71	02/14/1998	165.031	Female	Adult	Brown	29	White	30	White	Private
72	02/14/1998	164.310	Female	Adult	Red/Green	109	Red	27	White	Park
73	02/14/1998	165.073	Female	Adult	Brown	28	White	125	Red	Private
74	02/14/1998	164.625	Male	Adult	None	Trans	Yellow	26	White	Private
75	02/14/1998	165.232	Female	Adult	Brown	34	Red	34	White	Park
76	02/23/1998	165.392	Female	Adult	Yellow/Brown	31	Red	31	White	Park
77	02/25/1998	165.413	Female	Adult	Green/Yellow	35	Red	35	White	Park
78	02/24/1998	164.168	Female	Adult	Yellow	32	White	32	Red	Park
79	02/14/1998	164.366	Male	Adult	None	33	Red	Trans	Yellow	Private
80	02/28/1998	165.103	Female	Adult	Brown	None	None	41	Red	Private
81	02/28/1998	165.293	Female	Adult	Brown	43	Red	43	White	Park
82	02/27/1998	165.043	Female	Adult	Brown	44	Orange	33	White	Park
83	02/28/1998	165.166	Female	Adult	Brown	39	Red	38	White	Private
84	02/25/1998	165.242	Female	Adult	Brown/Red	41	White	40	Red	Private
85	02/25/1998	165.152	Female	Adult	Brown/Red	38	Red	39	White	Park
86	02/26/1998	165.053	Female	Adult	Green/Brown	40	White	42	White	Private
87	03/01/1998	165.432	Female	Adult	Brown	44	White	46	Red	Park
88	03/10/1998	165.421	Female	Adult	Brown	49	Red	48	Red	Park
89	03/10/1998	165.183	Female	Adult	Brown	47	Red	45	Red	Park

Table 5. White-tailed deer captured and marked within Valley Forge National Historical Park and surrounding private lands during 1998 (continued).

Deer ID	Capture Date	Frequency (MHz)	Sex	Age	Radio-collar Color(s)	Eag-tag Description[a] Left Number	Left Color	Right Number	Right Color	Capture Location
90	03/11/1998	165.191	Female	Adult	Brown	11	Orange	36	Red	Park
91	03/11/1998	165.284	Female	Adult	Green	50	Red	36	White	Park
92	03/11/1998	165.303	Female	Adult	Red/Black	45	White	44	Red	Park
93	03/12/1998	165.274	Female	Adult	Green/Black	30	Red	none	none	Park
94	03/12/1998	165.113	Female	Adult	Black	12	Orange	37	Red	Park
95	03/12/1998	165.525	Male	Adult	None	57	Orange	Trans	Yellow	Park
96	03/13/1998	164.373	Female	Adult	Red/Yellow	69	Red	70	Red	Park
97	03/18/1998	164.118	Female	Adult	Brown	66	Red	67	Red	Park
98	03/19/1998	164.326	Female	Adult	Black	31	Orange	35	Orange	Park
99	03/19/1998	164.365	Female	Adult	Green/Yellow	32	Orange	28	White	Park
100	03/20/1998	165.172	Female	Adult	Brown	34	Orange	20	Orange	Private

[a]Trans=ear-tag radio transmitter

Table 6. White-tailed deer captured and marked within Valley Forge National Historical Park and surrounding private lands during 1999.

Deer ID	Capture Date	Frequency (MHz)	Sex	Age	Radio-collar Color(s)	Eag-tag Description[a]				Capture Location
						Left		Right		
						Number	Color	Number	Color	
101	02/13/1999	164.365	Female	Adult	Brown	107	Yellow	108	Yellow	Park
102	02/14/1999	164.712	Female	Adult	Brown	104	Yellow	103	Yellow	Park
103	02/18/1999	164.818	Female	Adult	Brown	112	Yellow	111	Yellow	Park
104	02/18/1998	164.842	Female	Adult	Brown	106	Yellow	105	Yellow	Park
105	02/19/1999	164.625	Male	Adult	None	None	None	Trans	Yellow	Park
106	02/19/1999	164.968	Female	Adult	Brown	101	Yellow	102	Yellow	Park
107	02/20/1999	164.583	Male	Adult	None	Trans	Yellow	114	Yellow	Park
108	02/20/1999	164.983	Female	Adult	Brown	None	None	None	None	Private
109	02/21/1999	164.384	Male	Adult	None	None	None	Trans	Yellow	Park
110	02/21/1999	164.763	Female	Adult	Brown	116	Yellow	119	Yellow	Private
111	03/07/1999	164.152	Female	Adult	Brown	143	Yellow	144	Yellow	Private
112	03/07/1999	164.983	Female	Adult	Brown	128	Yellow	127	Yellow	Park
113	03/07/1999	164.788	Female	Adult	Brown	123	Yellow	124	Yellow	Park
114	03/08/1999	165.443	Female	Adult	Red/Yellow	109	Yellow	none	none	Private
115	03/08/1999	164.952	Female	Adult	Brown	129	Yellow	130	Yellow	Park
116	03/08/1999	165.243	Female	Adult	Red/Brown	121	Yellow	122	Yellow	Park
117	03/09/1999	164.894	Female	Adult	Brown	138	Yellow	139	Yellow	Private
118	04/01/1999	164.230	Female	Adult	Green/Brown	133	Yellow	134	Yellow	Private
119	04/01/1999	165.043	Female	Adult	Brown	120	Yellow	125	Yellow	Private
120	04/01/1999	165.443	Female	Adult	Red/Yellow	none	none	140	Yellow	Private

[a]Trans=ear-tag radio transmitter

Table 7. Observed number of all white-tailed deer (Obs.) and those marked (Mark) within Valley Forge National Historical Park during vehicle-based counts conducted at dusk during 1997.

	Compartment														
	1		2		3		4		5		Total	Marked			Pop.
Count	Obs.	Mark	Obs.	Mark	Obs.	Mark	Obs.	Mark	Obs.	Mark	Obs.	Obs.	Avail	SI[a]	Est.
1	164	4	163	9	128	2	51	2	130	6	636	23	26	0.88	719
2	143	5	120	6	109	1	68	1	71	4	511	17	27	0.63	812
3	193	4	100	5	93	3	53	3	85	3	524	18	27	0.67	786

[a]SI = Sighting index

Table 8. Observed number of all white-tailed deer (Obs.) and those marked (Mark) within Valley Forge National Historical Park during vehicle-based counts conducted at dusk during 1998.

	Compartment																
	1		2		3		4		5		7		Total	Marked			Pop.
Count	Obs.	Mark	Obs.	Mark	Obs.	Mark	Obs.	Mark	Obs.	Mark	Obs.	Mark	Obs.	Obs.	Avail.	SI[a]	Est.
1	117	7	96	5	135	8	194	8	51	6	7	0	600	34	50	0.68	872
2	102	8	91	2	136	11	157	5	20	0	4	0	510	26	50	0.52	973
3	112	7	72	4	116	8	124	3	74	7	0	0	498	29	51	0.57	876

[a]SI = Sighting index

Table 9. Observed number of all white-tailed deer (Obs.) and those marked (Mark) within Valley Forge National Historical Park during vehicle-based counts conducted at dusk during 1999.

	Compartment																
	1		2		3		4		5		7		Total	Marked			Pop.
Count	Obs.	Mark	Obs.	Mark	Obs.	Mark	Obs.	Mark	Obs.	Mark	Obs.	Mark	Obs.	Obs.	Avail.	SI[a]	Est.
1	168	9	110	9	124	7	102	3	72	9	4	0	580	37	61	0.61	956
2	148	7	108	7	178	9	92	5	100	7	4	0	630	35	61	0.57	1,098
3	111	8	92	8	157	7	90	3	70	6	2	0	522	32	61	0.52	995

[a]SI = Sighting index

Table 10. White-tailed deer population estimates within Valley Forge National Historical Park during 1997, 1998, and 1999.

Year	Marked Deer Available	Deer Counted		Sighting Index		Population Estimate	
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
1997	26, 27, 27	557	69	0.73	0.14	772	48
1998	50, 50, 51	536	56	0.59	0.08	913	59
1999	61, 61, 61	577	54	0.57	0.04	1,016	73

[a]Number of marked deer available during each of three surveys.

areas in compartments 2, 3, and 4 were counted simultaneously during each count to document movement among these compartments by radio-tagged deer. Park areas in other compartments were counted individually because there was little evidence of movement across these compartment boundaries.

Average number of deer counted in compartment 3 (quarry area) increased each year whereas counts in other compartments were more variable. Average number of deer counted in compartments 1, 2, and 5 decreased from 1997 to 1998 and increased in 1999 (Tables 7, 8, and 11).

The sighting index (SI) in the park decreased 19% from 1997 (SI=0.73) to 1998 (SI = 0.59), whereas index values for 1998 and 1999 (SI = 0.57) were similar (Table 10). Variation in sighting index values was minimal. Variation in sighting index values was greatest among counts during 1997 when only 27 deer were marked and available to be counted.

The sighting index is a ratio of the number of marked deer seen during a count relative to the number of marked deer known to be within the area of interest. These numbers are considered random variables and are dependent on many factors. Counts were done when conditions (weather, time of day, season, etc.) were as similar as possible. But, these counts were variable. Yet, within years the variation was relatively low and among years, by chance, 1998 and 1999 were identical, and somewhat different from 1997.

Population estimates within Valley Forge National Historical Park were 772, 913, and 1,016 deer during 1997, 1998, and 1999, respectively (Table 10). These estimates, based on sighting indices, suggested an 18% increase in population size during 1997-1998, followed by an 11% increase during 1998-1999. Variation among replicate counts was greatest during 1999.

Results from vehicle-based deer counts on private land surrounding VAFO (i.e., including results from all or portions of compartments 4, 5, 6, 7, and 8) were highly variable due to limited visibility around woodlots and structures. During 1997 surveys,

Table 11. Mean number of white-tailed deer counted during three replicate surveys within the portion of each of six compartments within Valley Forge National Historical Park during 1997, 1998, and 1999.

	Compartment											
	1		2		3		4		5		7	
Year	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
1997	167	25.11	128	32.19	110	17.52	57	9.292	95	30.83	NA	NA
1998	110	7.60	86	12.70	129	11.3	158	35.000	48	27.10	4	3.5
1999	142	28.90	103	9.90	153	27.2	95	6.400	81	16.80	3	1.2

19 to 39 deer were observed on private lands within compartment 5, (the only private lands surveyed during 1997); however, only one marked deer was observed during these surveys. Total deer observed on all private lands within survey compartments ranged from 59 to 109 during replicate counts in 1998, and from 42 to 77 during 1999 (Table 12). A maximum of 3 marked deer was observed on private lands during any replicate count during 1998 and 1999. These results suggested that sighting indices were lower than those observed in VAFO, but were too variable to be estimated during this study. Sighting indices from VAFO can not be applied to surrounding private lands. We could not estimate deer abundance, and hence density, for private lands due primarily to the obstructions (primarily buildings) that dominated the landscape.

The suggested driving routes for conducting future annual vehicle-based deer counts within VAFO are shown in Figure 5. Detailed instructions for conducting the surveys have been provided to park staff. In future years it will be impossible to calculate a sighting index and estimate population abundance without continued tracking of marked deer (Caughley and Sinclair 1994). The actual number and location of marked deer in the population cannot be determined on an annual basis if mortality and possible changes in the spatial distribution of marked deer cannot be documented. We recommend, however, that long-term monitoring of deer numbers continue and that the average number of deer counted in each compartment be used as a park-wide abundance index. A 1:1 correlation between the change in the index to the change in abundance can only be assumed. If a sighting index of 0.58 (average of the 1998 and 1999 sighting indices) is applied to future counts, the resulting value will be an index to, rather than an estimate of, abundance.

Home Range Analyses

A total of 5,634 independent locations (Appendix), 1,850 during 1997, 2,307 during 1998, and 1,477 during 1999, were used for the estimation of home range area (Tables 13, 14, and 15). Locations were only considered independent when greater than 6 hours had elapsed between previous or subsequent location estimates on the same

Table 12. Number of white-tailed deer, including those marked (in parentheses), observed within compartments outside of Valley Forge National Historical Park during vehicle-based counts conducted at dusk during 1997, 1998, and 1999.

	1997				1998					1999				
Count	5	6	7	8	4	5	6	7	8	4	5	6	7	8
1	33 (1)	-	-	-	0 (0)	31 (3)	11 (0)	11 (0)	22 (0)	5 (0)	6 (0)	1 (0)	3 (0)	27 (1)
2	19 (0)	-	-	-	3 (0)	55 (2)	4 (0)	20 (0)	26 (0)	1 (0)	34 (0)	11 (0)	12 (0)	11 (0)
3	39 (0)	-	-	-	1 (0)	34 (1)	5 (0)	2 (1)	17 (1)	0 (0)	27 (2)	5 (0)	12 (0)	33 (0)
Mean	30				1	40	7	11	22	2	22	6	9	24
SD	10				2	13	4	9	5	3	15	5	5	11

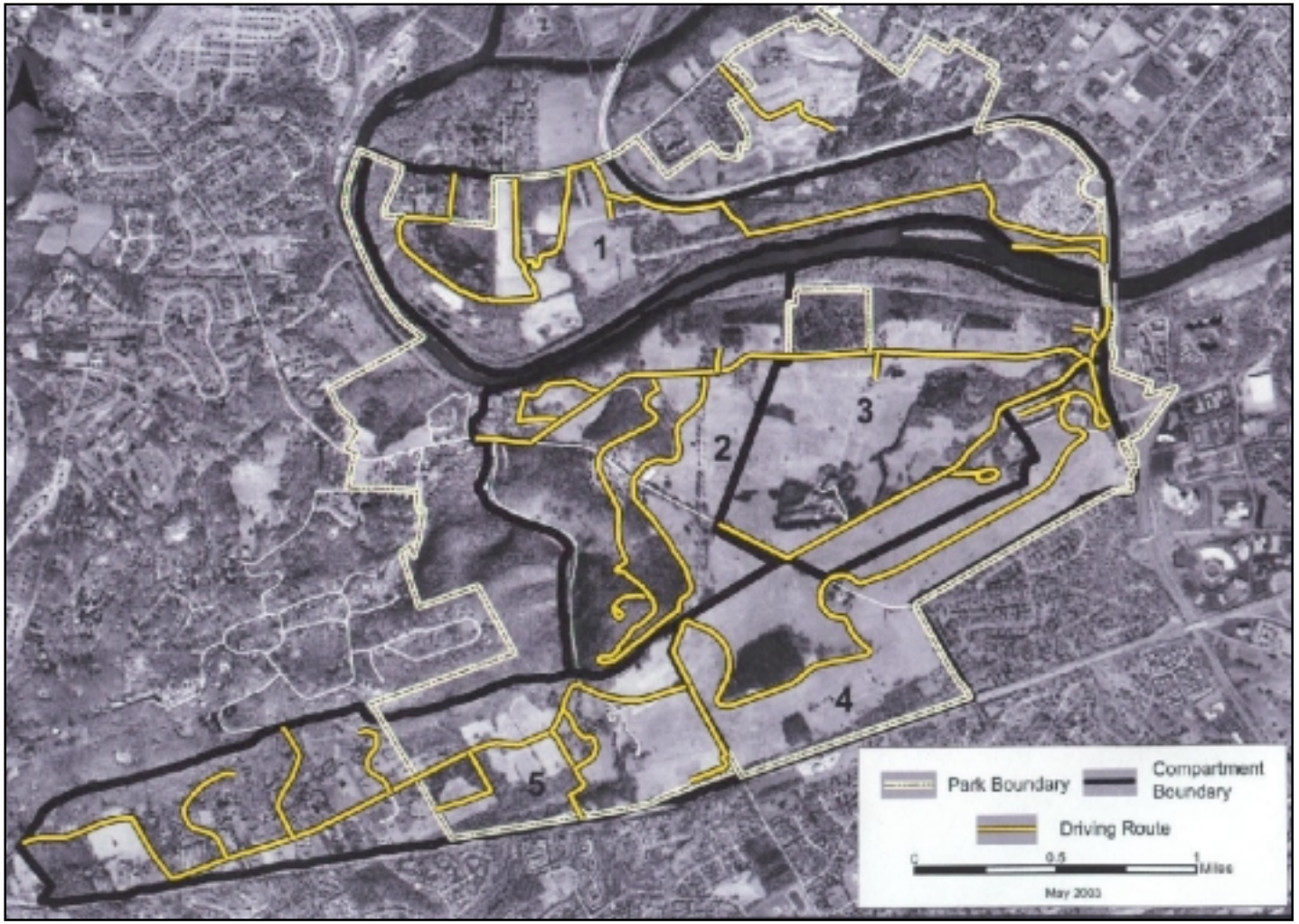

Figure 5. Driving routes for annual monitoring of white-tailed deer abundance within Valley Forge National Historical Park.

Table 13. Annual home range (ha) estimates (95% adaptive kernel and 100% minimum convex polygon) for white-tailed deer within Valley Forge National Historical Park and surrounding private lands during 1997.

Deer ID	Sex	Age	Number of locations	Annual home range area (ha) 95% Adaptive kernel	Annual home range area (ha) 100% Min. con. poly.
1	Female	Adult	85	25.92	75.04
2	Female	Adult	77	80.14	130.02
3	Male	Adult	41	66.44	93.50
4	Female	Adult	70	88.93	72.41
6	Female	Adult	80	93.05	134.64
7	Female	Juvenile	41	44.81	46.44
8	Male	Juvenile	48	130.02	211.66
10	Female	Adult	66	151.92	264.19
11	Female	Adult	64	59.09	134.16
12	Female	Adult	62	46.00	54.10
13	Female	Adult	90	46.83	79.20
14	Female	Adult	34	104.61	308.53
15	Female	Adult	44	106.05	96.10
16	Female	Adult	60	104.02	162.50
17	Female	Adult	30	108.56	112.18
18	Female	Juvenile	17	34.45	16.31
19	Female	Juvenile	48	143.98	358.78
20	Male	Juvenile	57	171.77	163.73
21	Female	Adult	46	129.13	190.29
22	Female	Adult	87	39.63	123.74
23	Female	Adult	49	59.88	65.39
24	Male	Juvenile	73	44.32	88.87
25	Female	Adult	41	23.53	25.72
26	Female	Adult	85	40.84	60.81
27	Male	Juvenile	38	209.09	166.61
28	Female	Adult	58	74.73	124.19
29	Female	Adult	53	67.94	77.29
32	Female	Adult	32	54.85	89.62
35	Male	Adult	33	100.92	108.57
39	Male	Juvenile	40	200.22	115.74
43	Female	Adult	20	45.32	43.65
45	Female	Adult	77	63.44	137.52

Table 14. Annual home range (ha) estimates (95% adaptive kernel and 100% minimum convex polygon) for white-tailed deer within Valley Forge National Historical Park and surrounding private lands during 1998.

Deer ID	Sex	Age	Number of locations	Annual home range area (ha)	
				95% Adaptive kernel	100% Min. con. poly.
1	Female	Adult	57	28.17	37.62
2	Female	Adult	46	109.60	93.33
4	Male	Adult	43	79.18	62.59
6	Female	Adult	51	71.11	103.70
8	Male	Adult	32	187.48	186.05
10	Female	Adult	53	149.91	226.95
11	Female	Adult	49	124.78	205.88
14	Female	Adult	25	180.67	165.30
15	Female	Adult	39	70.06	49.90
16	Female	Adult	50	139.75	175.81
17	Female	Adult	40	110.10	77.89
20	Male	Adult	49	89.65	97.03
22	Female	Adult	55	40.51	71.16
24	Male	Adult	37	50.31	58.25
25	Female	Adult	28	50.11	39.00
26	Female	Adult	52	51.25	45.96
28	Female	Adult	28	98.87	97.31
29	Female	Adult	15	71.92	97.65
39	Male	Adult	31	186.51	160.26
45	Female	Adult	59	75.67	75.36
46	Female	Adult	40	100.05	84.44
47	Female	Adult	38	115.36	148.24
48	Female	Adult	37	67.54	74.26
49	Female	Adult	33	53.11	36.79
50	Female	Adult	34	39.31	28.31
51	Male	Adult	35	56.04	38.66
52	Female	Adult	33	214.95	137.39
54	Female	Adult	35	196.53	142.98
55	Female	Adult	18	136.13	108.53
56	Male	Adult	27	130.58	93.81
57	Female	Adult	24	80.70	42.22
58	Male	Adult	26	104.27	65.62
59	Female	Adult	17	258.47	90.79
60	Female	Adult	17	488.35	276.95
61	Female	Adult	28	145.86	127.23
62	Female	Adult	19	156.71	84.74
63	Female	Adult	32	41.74	25.83
64	Female	Adult	30	67.87	76.36
67	Female	Adult	35	51.08	39.87
68	Female	Adult	39	33.24	24.31
69	Female	Adult	21	266.61	199.70
70	Female	Adult	24	163.06	92.29
71	Female	Adult	27	132.68	133.26

Table 14. Annual home range (ha) estimates (95% adaptive kernel and 100% minimum convex polygon) for white-tailed deer within Valley Forge National Historical Park and surrounding private lands during 1998 (continued).

Deer ID	Sex	Age	Number of locations	Annual home range area (ha)	
				95% Adaptive kernel	100% Min. con. poly.
72	Female	Adult	21	86.73	50.96
73	Female	Adult	31	68.51	71.75
78	Female	Adult	17	34.08	19.28
80	Female	Adult	24	37.57	27.20
81	Female	Adult	33	130.01	109.55
82	Female	Adult	13	57.46	28.58
83	Female	Adult	23	124.64	71.31
84	Female	Adult	20	75.15	46.35
85	Female	Adult	19	188.06	77.91
86	Female	Adult	28	72.19	68.76
87	Female	Adult	27	64.98	51.04
88	Female	Adult	19	57.96	31.35
89	Female	Adult	37	103.64	113.54
90	Female	Adult	37	93.70	79.00
91	Female	Adult	31	44.21	36.91
92	Female	Adult	25	131.43	65.04
93	Female	Adult	27	106.81	125.24
94	Female	Adult	34	157.97	132.05
95	Male	Adult	14	67.93	45.25
96	Female	Adult	31	116.67	89.25
97	Female	Adult	26	130.97	75.16
98	Female	Adult	33	35.41	31.30
99	Female	Adult	21	136.51	109.75

Table 15. Annual home range (ha) estimates (95% adaptive kernel and 100% minimum convex polygon) for white-tailed deer within Valley Forge National Historical Park and surrounding private lands during 1999.

Deer ID	Sex	Age	Number of locations	Annual home range area (ha)	
				95% Adaptive kernel	100% Min. con. poly.
1	Female	Adult	34	49.40	45.98
2	Female	Adult	33	151.13	171.50
4	Female	Adult	40	115.70	110.31
6	Female	Adult	34	116.57	103.73
10	Female	Adult	39	96.41	71.58
11	Female	Adult	20	98.99	75.51
15	Female	Adult	18	50.27	33.88
16	Female	Adult	35	83.86	103.19
22	Female	Adult	28	89.32	56.21
25	Female	Adult	24	59.22	44.68
26	Female	Adult	28	78.56	76.22
28	Female	Adult	24	33.95	29.31
41	Female	Adult	22	110.23	125.74
45	Female	Adult	31	98.29	77.96
46	Female	Adult	41	118.08	93.41
47	Female	Adult	30	158.51	142.24
48	Female	Adult	26	107.61	88.44
49	Female	Adult	38	47.69	29.61
52	Female	Adult	25	178.79	110.55
54	Female	Adult	29	139.91	107.27
63	Female	Adult	22	45.19	26.23
64	Female	Adult	19	44.42	29.56
68	Female	Adult	35	65.91	55.35
69	Female	Adult	16	215.92	126.52
71	Female	Adult	20	103.15	124.80
72	Female	Adult	24	121.43	66.10
75	Female	Adult	36	59.19	68.32
76	Female	Adult	17	92.91	31.69
77	Female	Adult	22	175.63	173.21
80	Female	Adult	25	57.47	93.57
81	Female	Adult	27	217.89	314.43
83	Female	Adult	18	45.13	26.73
84	Female	Adult	18	65.64	39.77
86	Female	Adult	17	161.07	80.75
87	Female	Adult	17	141.60	138.53
89	Female	Adult	35	137.42	119.17
90	Female	Adult	46	100.30	99.38
91	Female	Adult	29	45.58	33.81
94	Female	Adult	26	92.57	67.66
96	Female	Adult	40	79.60	86.43
97	Female	Adult	17	105.24	69.29
98	Female	Adult	30	112.83	169.56
99	Female	Adult	16	83.11	66.73
101	Female	Adult	21	68.30	41.84
111	Female	Adult	20	80.34	32.14
113	Female	Adult	17	39.98	25.62

individual. Sampling intensity was relatively similar among diel periods; 15.2 percent of all locations were collected during 0000 to 0600 hrs, 28.9 percent were collected during 0601 to 1200 hrs, 27.3 percent were collected during 1201 to 1800 hrs, and 28.6 percent were collected during 1801 to 2400 hrs. Comparisons of home range area versus sampling intensity suggested relatively few independent locations were needed to estimate annual home range for male or female white-tailed deer.

Annual home range area, as estimated with 100% minimum convex polygon method, was correlated with sampling intensity if less than 16 radio-telemetry determined locations were used (r^2 = 0.453, P = 0.002), but was not correlated (r^2 = 0.160, P =0.05) if a greater number of locations was used (Figure 6). Based on these relationships, only annual home range estimates based on greater than 16 radio-telemetry determined locations were used to calculate annual mean home range area and to compare home range area between sexes and among years.

Most monitored deer occupied annual home range areas that were less than 200 ha (Tables 13, 14, 15, and 16). The largest average annual home range estimates were attributed to several juvenile males that were equipped with ear tag transmitters in 1997. Adult female average annual home range areas, as estimated by the 100% minimum convex polygon estimates, were comparable (33, 23, and 16 percent difference for 1997, 1998, and 1999, respectively) to 95% adaptive kernel estimates.

Furthermore, individual home range estimates (100% minimum convex polygon and 95% adaptive kernel) were correlated (Table 17). There was no correlation (-0.28 <r <0.46, P >0.05) between the number of telemetry locations and home range area 100% minimum convex polygon or 95% adaptive kernel) for adult females for any year (1997, 1998, and 1999).

Annual home range estimates for adult females were not normally distributed (D=0.11, $P \leq 0.01$). There was no annual difference in median home range size of adult females during 1997, 1998, and 1999 as estimated by the 100% minimum convex polygon method (H_2 = 5.37, P = 0.068) or the 95% adaptive kernel method (H_2 = 3.95, P = 0.139).

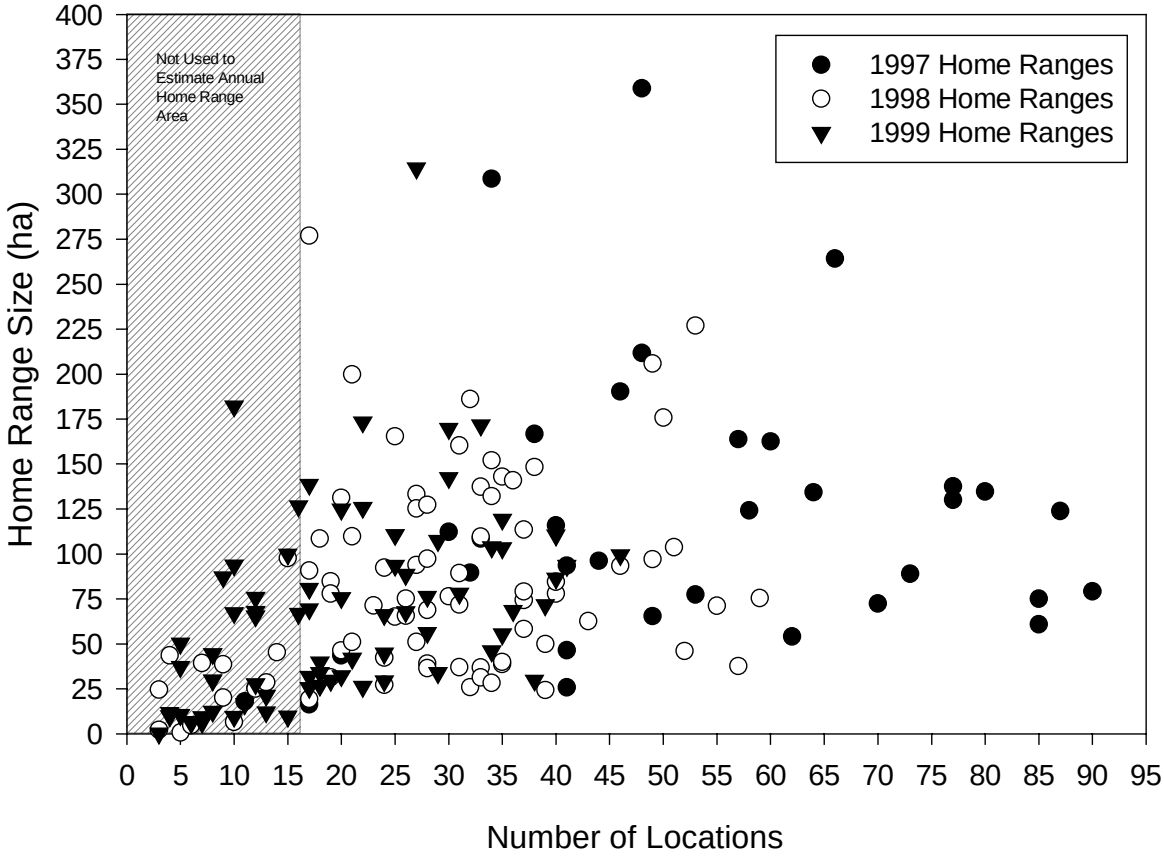

Figure 6. Annual sampling intensity versus home range area for white-tailed deer captured, marked, and monitored in Valley Forge National Historical Park and surrounding lands during 1997, 1998, and 1999.

Table 16. Mean annual home range (ha) estimates (95% adaptive kernel and 100% minimum convex polygon) for adult and juvenile (< 1 year old) white-tailed deer monitored within Valley Forge National Historical Park and surrounding private lands during 1997, 1998, and 1999.

			Annual home range area (ha)			
			95% Adaptive kernel		100% Min. con. poly.	
Year	Cohort	n	$\bar{x}$	SE	$\bar{x}$	SE
1997	Adult female	22	77.80	7.80	129.10	18.20
	Juvenile female	3	42.03	3.83	47.30	18.20
	Adult male	2	83.68	17.25	101.04	7.35
	Juvenile male	5	151.08	30.04	149.32	21.41
1998	Adult female	57	109.41	9.99	88.57	7.26
	Juvenile female	0				
	Adult male	9	105.77	17.38	89.72	17.16
	Juvenile male	0				
1999	Adult female	46	98.70	6.73	84.88	7.97
	Juvenile female	0				
	Adult male	0				
	Juvenile male	0				

Table 17. Pearson correlation coefficients (r) of white-tailed deer home range estimates (100% minimum convex polygon vs. 95% adaptive kernel) within Valley Forge National Historical Park and surrounding private lands during 1997, 1998, and 1999.

		1997			1998			1999			1997, 1998, and 1999		
	Category	n	*r*	*P*[a]	n	*r*	*P*[a]	n	*r*	*P*[a]	n	*r*	*P*[a]
Male	Juvenile	5	0.37	0.5371							5	0.37	0.5371
	Adult	2	1.00		9	0.94	<0.0001				11	0.90	0.0002
Female	Juvenile	3	.99	0.0040							3	0.99	0.0040
	Adult	22	0.73	<0.0001	57	0.78	<0.0001	46	0.81	<0.001	125	0.67	<0.0001
All		32	0.62	<0.0001	66	0.75	<0.0001	46	0.81	<0.001	144	0.66	<0.0001

[a]Probability of a Type I error.

One hundred percent minimum convex polygon home range estimates for adult males were normally distributed (D = 0.175, P > 0.15), as were 95% adaptive kernel estimates (D = 0.124, P > 0.15), although sample size was limited for males. There was no difference in mean annual home range area of adult males based on the 100% minimum convex polygon method (t = 0.24, P = 0.34) or the 95% adaptive kernel method (t = 0.22, P = 0.84) between 1997 and 1998. No estimates for males were available during 1999 due to battery expiration of the ear-tag transmitters.

Composite (multi-year) home range area was estimated for individuals that were monitored for 2 and 3 consecutive years to assess home range fidelity. Based on 100% minimum convex polygon estimates, median home range area of adult females increased significantly with the number of consecutive years that an individual animal was monitored (H_2 = 22.46, P < 0.001). Median composite (multi-year) home range area was 46.44 ha for deer monitored one year or less, 116.4 ha for deer monitored for 2 continuous years, and 159.9 ha for deer monitored for three continuous years. This result, combined with the fact that annual home range size did not change significantly among years and that home range area was not correlated with sampling intensity, suggested adult females might have exhibited moderate shifts in intensity of landscape use among years.

Composite (multi-year) male home range area also differed with the number of years a deer was monitored ($F_{2,10}$ = 6.90, P = 0.018). Mean composite home range area for adult males was 90.6 ha for individuals monitored for 1 year or less, 205.8 ha for those monitored for two continuous years, and 151.8 ha for those monitored into the third year. Locations on males were only collected through direct observation (not radio telemetry) during the third year of monitoring.

Home Ranges and the Park Boundary

Thirty-seven percent of composite (multi-year) home ranges for females contained 100% of the home range area within the boundaries of the park, whereas fifty-four

percent (49 of 90) of composite home ranges for females contained greater than 90% of the home range area within the boundaries of the park. Twenty-two females (24%) occupied composite home ranges with 50-90% of the home range area within the park boundary, and 19 females had composite home ranges with less than 50% of the home range area within the park. Sixty percent (9 of 15) of male composite home ranges had greater than 90% of the area within the park. One male had 67% of its composite home range area within the park, and five males had less than 50% of their individual composite home range area within the park boundary.

There was no correlation between composite (multi-year) home range area and the percent of the home range contained within the park boundary for either males (r = 0.339, P = 0.236) or females (r = 0.134, P = 0.249). Median composite home range area (117.52 ha) for females that had greater than 50% of the home range area within the park boundary was not different (W = 2461.0, P = 0.3247) from median home range area (90.91 ha) for females that had greater than 50% of the home range area outside the park. Similarly, mean composite home range area (81.1 ha) for males with greater than 50% of the home range area outside of the park boundary was not different (t = -1.58, P = 0.14) from medium home range area (134.0 ha) for males that had greater than 50% of the home range area within the park.

For the 66 adult female deer captured within the park, the mean proportion of radio-telemetry locations within the park was 0.8951 (SE = 0.023). Whereas, for the 18 adult female deer captured on private property adjacent to the park, the mean proportion of radio-telemetry locations within the park was 0.5230 (SE = 0.0945). These proportions were different (P<0.001).

Movements Relative to the Park Boundary

Female deer that occupied home ranges with greater than 50% of their annual home range area within the park were located an average of 122 m (SD = 171.2) beyond the park boundary (Figure 7). The maximum distance that one of these females traversed beyond the park boundary was 1,094 m (3,589 ft.). Movements by these females

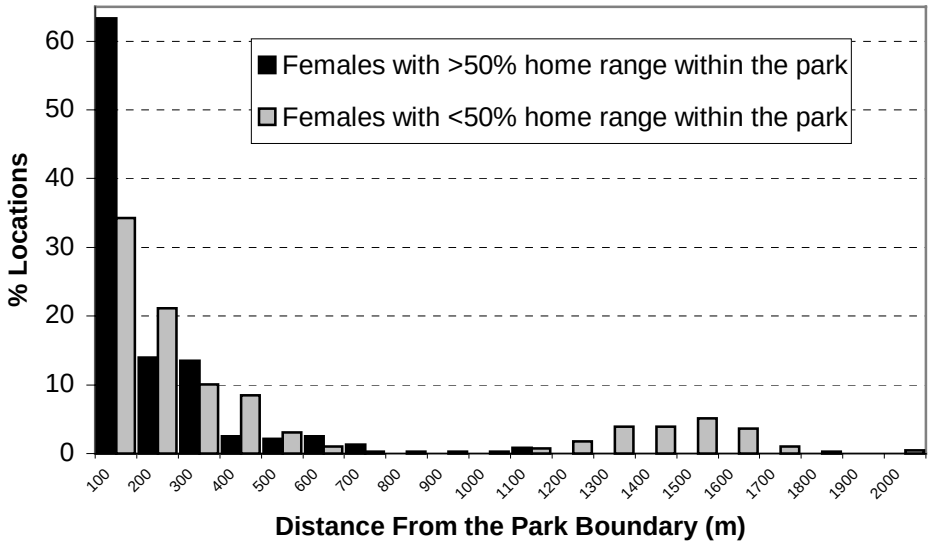

Figure 7. Percentage of female white-tailed deer radio locations outside the park relative to the Valley Forge National Historical Park boundary during 1997, 1998, and 1999 combined.

beyond the park boundary varied by time of day, with the greatest movements occurring during the late afternoon period (1200-1800 hours) (F = 3.32, d.f.=3,235, *P* = 0.021). The average distance outside the park boundary for females that occupied home ranges with less than 50% of their annual home range area within the park was 404 m (SD=484). The maximum distance that one of these females traversed beyond the park boundary was 1,985 m (6,512 ft.). Distance from the park boundary was greatest during 1800-2400 hours and was least during late afternoon periods (1200-1800 hours) (F=3.39, d.f.=3,386, *P* = 0.018).

Locational data for males were limited because during 1997 and 1998 only four males were monitored for two consecutive years, and seven males were monitored for a single year; no males were monitored in 1999. Twelve annual home ranges of males were 100% within the boundary of the park and another was 98% within the park. The remaining two annual home ranges, of deer that were monitored during only one year, were 50% or greater outside of the park. The annual home range area of one of these two males was approximately 60% outside of the park and was centered on the northern park boundary. The farthermost distances of this male's annual home range area outside the park ranged between 0.25 to 0.50 km from the park boundary. The other male had an annual home range area greater than 95% outside of the park, centered approximately 1.6 km from the park's western boundary. He was once located in the park 0.5 km east of the same boundary.

Habitat Composition of Home Ranges

Female home ranges were comprised primarily of deciduous forest and meadow cover types (Table 18). Percent composition of deciduous forest within female home ranges varied from 0 to 87% during 1997, 1998, and 1999. Percent composition of forested areas (deciduous forest, conifer, and developed forest cover types) within female home ranges averaged 49, 43, and 43% during 1997, 1998, and 1999, respectively. There was no difference in percent composition of forested cover within female home ranges among years ($F_{2,143} = 1.44$, $P = 0.241$). Average composition of meadow cover within

Table 18. Percent cover-type composition of female white-tailed deer home ranges (100% minimum convex polygon estimates) within Valley Forge National Historical Park and surrounding private lands during 1997, 1998, and 1999.

	1997				1998				1999			
Cover Type	$\bar{x}$	SD	Min	Max	$\bar{x}$	SD	Min	Max	$\bar{x}$	SD	Min	Max
Deciduous forest	37.5	19.6	3.0	87.3	34.7	18.2	0.0	70.9	36.3	19.3	0.0	72.6
Developed forest	9.2	19.8	0.0	67.8	6.4	15.6	0.0	70.3	5.1	14.8	0.0	69.4
Conifer forest	2.9	3.6	0.0	16.5	1.9	2.4	0.0	10.9	1.8	2.1	0.0	8.2
Meadow	37.0	26.8	0.0	79.3	40.6	29.6	0.0	93.3	40.9	29.2	0.0	83.9
Field	3.9	7.7	0.0	26.0	5.4	11.1	0.0	46.7	4.3	9.6	0.0	44.3
Maintained lawn	0.9	2.1	0.0	8.7	1.1	2.6	0.0	12.0	0.9	3.0	0.0	17.0
Agriculture	3.2	9.4	0.0	43.7	2.6	7.7	0.0	37.3	4.2	11.4	0.0	58.2
Unvegetated	0.2	0.3	0.0	1.2	0.2	0.5	0.0	2.8	0.2	0.3	0.0	1.5
Residential	3.4	6.1	0.0	21.3	4.3	8.7	0.0	35.8	4.6	14.4	0.0	87.1

female home ranges was 37, 41, and 41% during 1997, 1998, and 1999, respectively. There was no difference in percent composition of meadow cover within female home ranges among years ($F_{2,143}$ = 0.05, P = 0.953). Other cover types typically comprised <10% of annual female home range area (Table 18).

Annual home ranges of females with greater than 50% of the home range area within the park contained less forest cover types (deciduous forest, developed forest, and conifer forest) and more herbaceous cover types (e.g., fields and meadows) than did annual home ranges of females with greater than 50% of the home range area outside the park (Table 19). Agricultural cover types comprised, on average, 11 to 18% of annual home range area for females with greater than 50% of the home range area outside the park, and <2% of annual home range area for females with greater than 50% of the home range area within the park. Residential areas comprised, on average, 7 to 23% of annual home range area of females with greater than 50% of the home range area outside the park and approximately 3% of home range area of females with greater than 50% of the home range area within the park.

Annual home range area of females with greater than 50% of the home range area within the park was positively correlated to the percent composition of meadows (r = 0.314, P < 0.001) and was inversely related to percent composition of deciduous forest cover (r = -0.25, P = 0.004). No other significant relationship between cover-type composition and annual female home range size was detected.

Male home ranges were also primarily comprised of deciduous forest and meadow cover types (Table 20). Average composition of forest types (deciduous forest, developed forest, and conifer forest) within male home ranges was 54, 52, and 51% during 1997, 1998, and 1999, respectively. Percent composition of forest cover did not differ within male home ranges among years ($F_{2,23}$ = 0.02, P = 0.98). Average composition of meadow cover within annual male home ranges was 28, 31, and 25% during 1997, 1998, and 1999 respectively. Percent composition of meadow cover within male home ranges was not different among years ($F_{2,23}$ = 0.32, P = 0.733).

Table 19. Percent cover-type composition of home range area for female white-tailed deer that had greater than 50% home range area within Valley Forge National Historical Park and those that had greater than 50% home range area outside the park boundary during 1997, 1998, and 1999.

	1997				1998				1999			
	Outside		Within		Outside		Within		Outside		Within	
Cover Type	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Deciduous forest	29.1	12.0	41.9	19.7	37.5	20.8	36.5	19.7	43.4	26.3	36.9	18.2
Developed forest	27.7	28.8	0.6	1.5	13.6	22.4	2.2	7.5	7.5	19.3	2.0	7.0
Conifer forest	1.3	1.3	3.3	4.0	0.7	1.9	2.1	2.4	0.5	0.9	1.9	2.1
Meadow	7.1	8.1	48.0	21.6	4.7	6.3	49.7	25.2	6.7	13.9	50.4	25.6
Field	8.1	10.4	1.3	3.4	9.5	11.0	3.6	10.3	6.6	10.5	2.5	7.5
Maintained lawn	1.9	2.3	0.2	0.4	4.0	4.1	0.1	0.8	5.1	6.7	0.2	0.9
Agriculture	14.2	17.7	0.6	2.7	10.6	12.8	0.9	4.6	18.0	19.8	1.2	4.7
Unvegetated	0.0	0.1	0.3	0.3	0.0	0.0	0.3	0.5	0.0	0.1	0.2	0.4
Residential	6.7	7.9	2.8	5.7	11.9	12.6	2.9	8.6	8.3	23.2	2.8	8.8

Table 20. Percent cover-type composition of male white-tailed deer home ranges (100% minimum convex polygon estimates) within Valley Forge National Historical Park and surrounding private lands during 1997, 1998, and 1999.

	1997				1998				1999			
Cover Type	$\bar{x}$	SD	Min	Max	$\bar{x}$	SD	Min	Max	$\bar{x}$	SD	Min	Max
Deciduous forest	41.1	17.4	18.2	65.0	44.2	25.5	16.35	95.7	37.7	36.6	0	73.0
Developed forest	6.1	16.2	0	42.9	4.5	10.4	0	30.7	0	0	0	0
Conifer forest	3.0	2.9	0.9	8.96	2.8	4.2	0	14.3	1.5	2.6	0	4.5
Meadow	39.4	26.0	2.4	73.9	35.5	30.7	0	80.8	41.3	13.9	26.9	54.6
Field	3.6	7.8	0	21.2	1.8	4.0	0	11.1	0.1	0.3	0	0.4
Maintained lawn	1.4	2.3	0	4.9	0.5	1.4	0	4.7	0	0	0	0
Agriculture	2.6	6.8	0	17.9	5.2	11.6	0	31.3	0	0	0	0
Unvegetated	0.2	0.3	0	0.9	0.2	0.4	0	1.3	0.1	0.1	0	0.2
Residential	1.3	3.2	0	8.4	3.5	7.7	0	19.9	0	0	0	0

Annual home range area of males with greater than 50% of the home range area within the park was positively correlated with percent composition of meadow cover (r = 0.608, P = 0.003) and was inversely correlated with percent composition of forest cover (deciduous forest, conifer, and developed forest types) (r = -0.38, P = 0.089). No other significant relationship between cover-type composition and annual male home range area was detected.

Annual home ranges of males with greater than 50% of the home range area within the park contained less forest cover (deciduous forest, developed forest, and conifer forest) than did males with greater than 50% of the home range area outside the park during 1997 but not during 1998 (Table 21). Agricultural cover comprised, on average, 9 and 19% of annual home range area for males with greater than 50% of the home range area outside the park, during 1997 and 1998, respectively.

Residential areas comprised 5 and 13% of annual home range area for males with greater than 50% of the home range area outside the park; no male home ranges contained residential cover types within the park.

Cover-type Use Within the Park

Female deer that had greater than 50% of the home range area within the park did not use habitats in proportion to their availability during 1997 (χ^2_7 = 107.98, P < 0.001), 1998 (χ^2_7 = 146.63, P < 0.001), or 1999 (χ^2_7 = 139.46, P < 0.001) (Figure 8). Females used the meadow cover type more than expected and mowed lawn areas less than expected during all years. Deciduous forest areas were used less than expected during 1998 and 1999 and were used in proportion to availability in 1997 (Table 22). Similar patterns of habitat selection were evident from combined three-year analysis of use (Figure 9).

Table 21. Percent cover-type composition of home range area for male white-tailed deer that had greater than 50% home range area within Valley Forge National Historical Park and those that had greater than 50% home range area outside the park boundary during 1997, 1998, and 1999.

	1997				1998				1999			
	Outside		Within		Outside		Within		Outside		Within	
Cover Type	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Deciduous forest	34.1	22.5	43.9	17.2	31.9	15.3	48.8	27.8			37.7	36.6
Developed forest	21.5	30.3	0.0	0.0	16.6	15.5	0.0	0.0			0.0	0.0
Conifer forest	2.8	2.2	3.1	3.3	2.4	3.2	3.0	4.7			1.5	2.6
Meadow	6.8	6.2	52.5	16.1	7.9	4.9	45.9	29.8			41.3	13.9
Field	12.1	12.9	0.2	0.3	3.7	6.4	1.1	2.9			0.1	0.2
Maintained lawn	4.7	0.3	0.0	0.0	1.7	2.6	0.0	0.0			0.0	0.0
Agriculture	8.9	12.6	0.0	0.0	18.9	16.7	0.0	0.0			0.0	0.0
Unvegetated	0.0	0.0	0.2	0.4	0.0	0.0	0.3	0.5			0.1	0.1
Residential	4.5	5.6	0.0	0.0	12.6	11.0	0.0	0.0			0.0	0.0

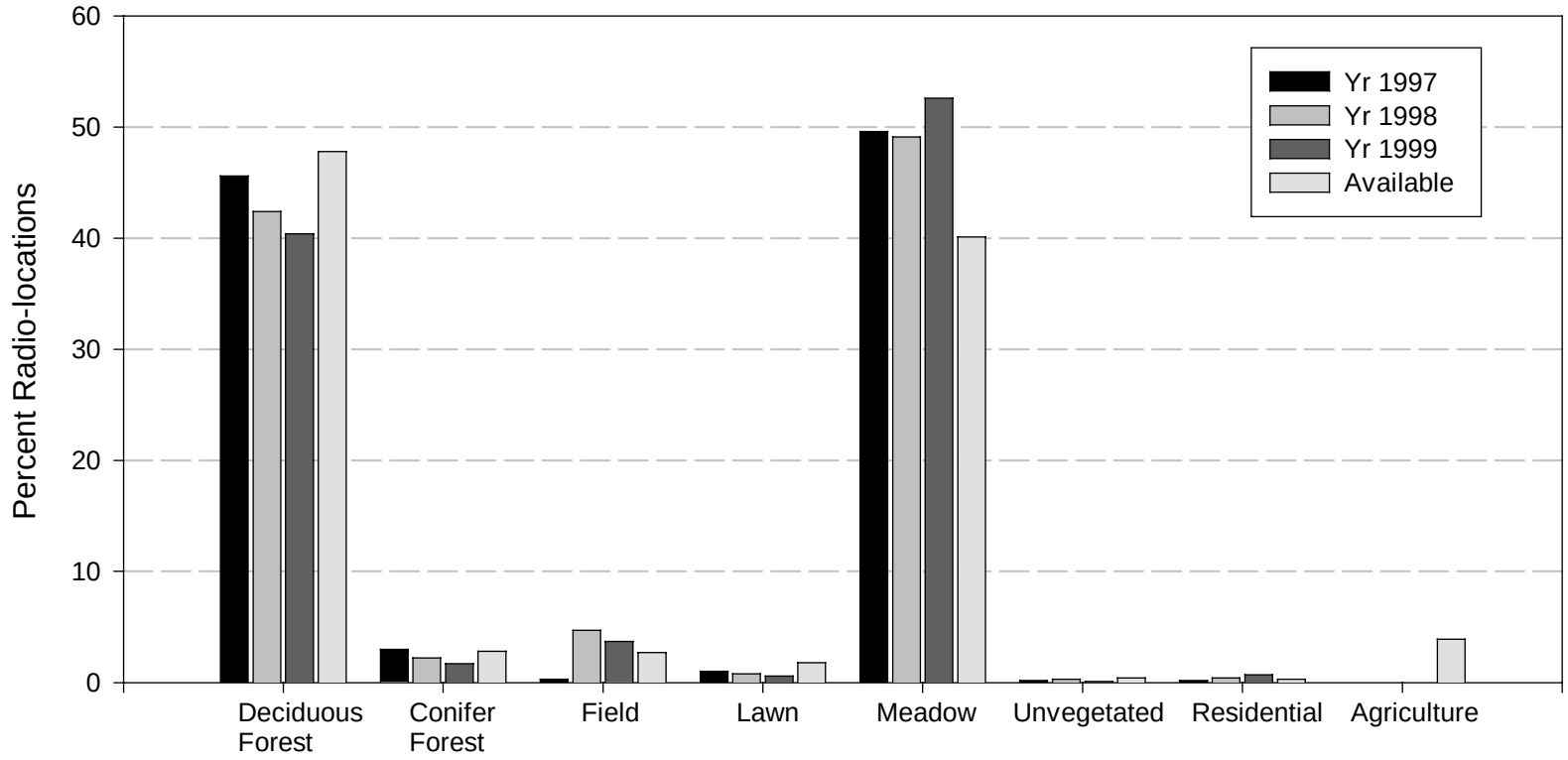

Figure 8. Use versus availability of cover types by female white-tailed deer that had greater than 50% home range area within Valley Forge National Historical Park during 1997, 1998, and 1999.

Table 22. Availability and use of cover types by female white-tailed deer that had greater than 50% home range area within Valley Forge National Historical Park during 1997, 1998, and 1999.

		1997		1998		1999	
Cover type	Available (%)	Locations (%)	95% CI	Locations (%)	95% CI	Locations (%)	95% CI
Deciduous forest[a]	47.8	45.6	41.7 - 49.5	42.5	39.2 - 45.8	40.5	36.6 - 44.3
Conifer forest	2.8	3.0	1.6 - 4.4	2.2	1.2 - 3.1	1.7	0.7 - 2.7
Meadow	40.1	49.6	45.7 - 53.5	49.1	45.7 - 52.5	52.6	48.7 - 56.5
Field	2.7	0.3	0.0 - 0.8	4.7	3.3 - 6.2	3.7	2.2 - 5.2
Maintained lawn	1.8	1.0	0.2 - 1.7	0.8	0.2 - 1.5	0.6	0.0 - 1.3
Agriculture	3.9	0.0	N/A	0.0	N/A	0.0	N/A
Unvegetated	0.4	0.2	0.0 - 0.6	0.3	0.0 - 0.7	0.1	0.0 - 0.1
Residential	0.3	0.2	0.0 - 0.6	0.4	0.0 - 0.8	0.7	0.0 - 1.4

[a]Includes developed forest cover type

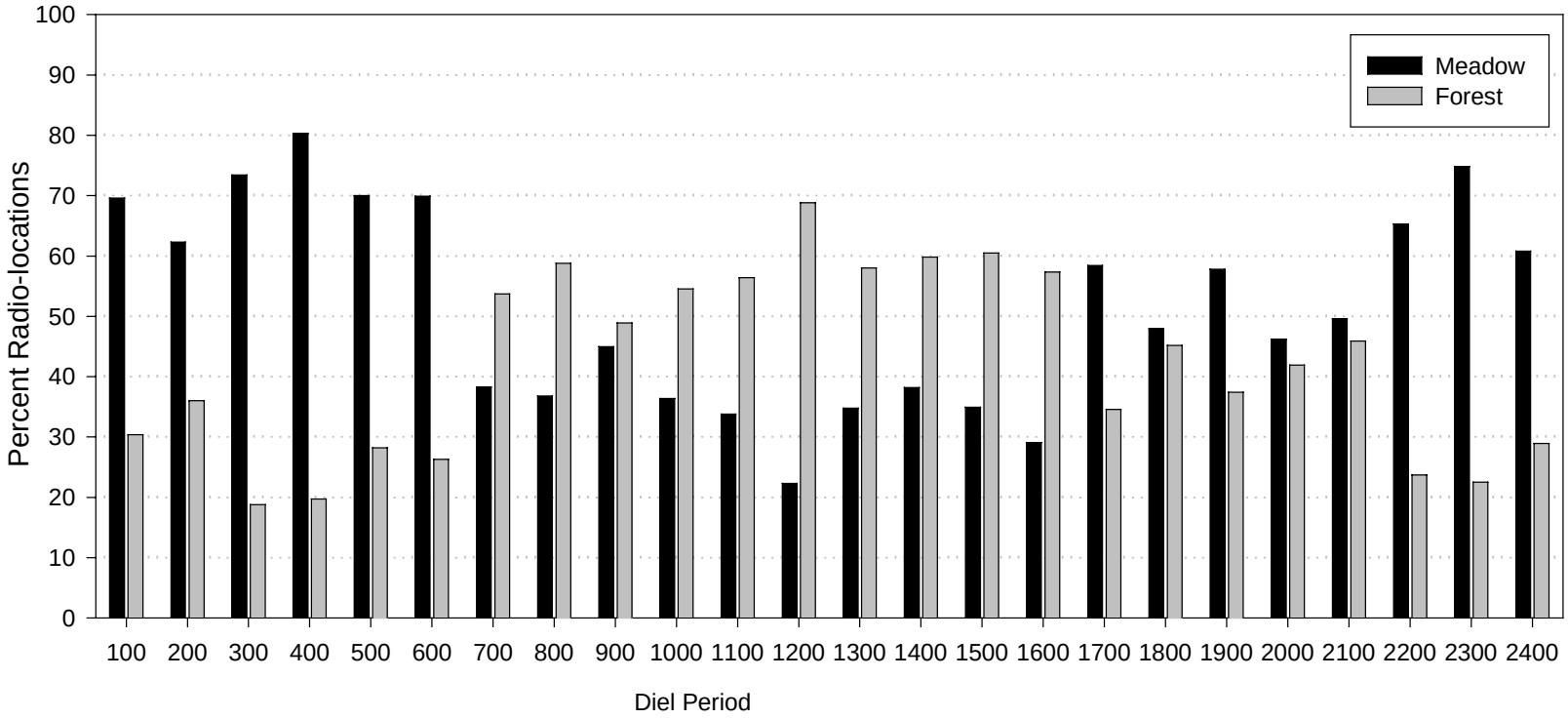

Figure 9. Diel use of meadow and forest cover types by female white-tailed deer that had greater than 50% home range area within Valley Forge National Historical Park during 1997, 1998, and 1999 combined.

Females exhibited diel shifts in habitat use with meadow and field cover types being used more frequently during the nocturnal period (e.g., 2200 - 0600 hours), and forest cover-types used more frequently during diurnal periods (Figure 9). Females were frequently located in meadows during all periods. The lowest percent use of the meadow cover-type and highest percent use of forest cover types occurred within the period of 1200-1300 hours when < 25% of female locations were associated with meadows. Approximately 51% of female locations were associated with meadows during 1700-1900 hours, the diel period during which vehicle-based surveys were conducted.

Male deer that had greater than 50% of the home range area within the park did not use park habitats in proportion to their availability during 1997 ($\chi^2_7 = 26.36$, $P < 0.001$), and 1998 ($\chi^2_7 = 33.63$, $P < 0.001$) (Table 23). Limited sample size of transmitting males precluded analysis of habitat selection for males during 1999. Males used meadows more than expected during 1998 and used meadows in proportion to their availability during 1997 (Figure 10). Male deer used mowed lawns, residential areas and agricultural areas within the park less than expected during 1997 and 1998. Similar patterns of use were evident on a three-year combined basis ($\chi^2_7 = 45.11$, $P < 0.001$) (Table 24).

Males exhibited more divergent diel use of meadow and forest cover type than did females (Figure 11). Males were more often located in forest habitats and less often located in meadow habitats during diurnal periods than were females. Similarly, a greater proportion of male locations were associated with meadow habitats during nocturnal periods than were female locations. Approximately 48% of male locations were associated with meadow cover types during 1700-1900 hours, the diel period during which vehicle-based surveys were conducted.

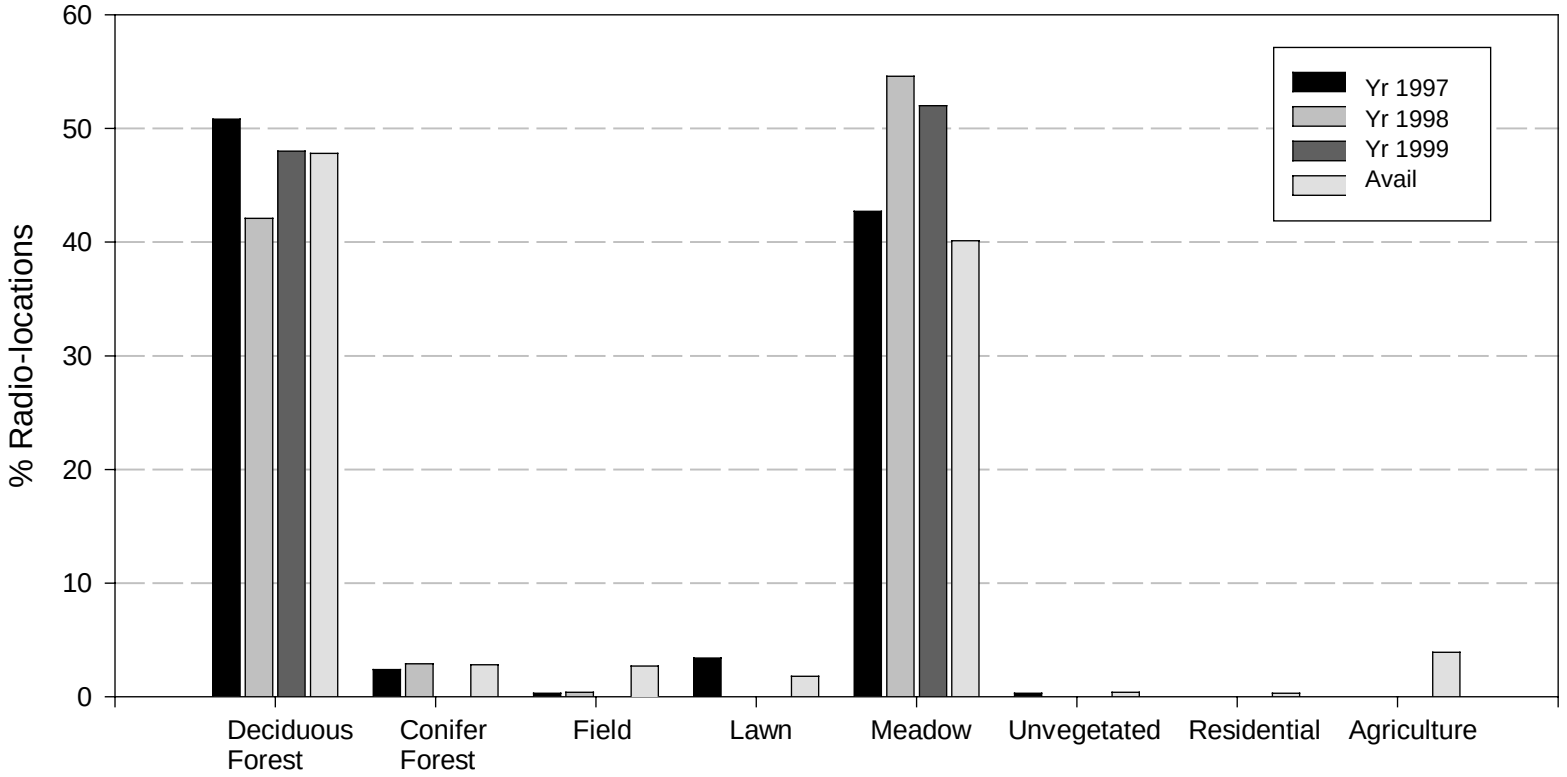

Figure 10. Use versus availability of cover types by male white-tailed deer that had greater than 50% home range area within Valley Forge National Historical Park during 1997, 1998, and 1999.

Table 23. Availability and use of cover types by male white-tailed deer that had greater than 50% home range area within Valley Forge National Historical Park during 1997, 1998, and 1999.

		1997		1998		1999	
Cover type	Available (%)	Locations (%)	95% CI	Locations (%)	95% CI	Locations (%)	95% CI
Deciduous forest[a]	47.8	50.8	42.8 - 58.8	42.1	33.4 - 50.8	48.0	N/A
Conifer forest	2.8	2.4	0.0 - 4.8	2.9	0.0 - 5.9	0.0	N/A
Meadow	40.1	42.7	34.8 - 50.6	54.6	45.7 - 52.5	52.0	N/A
Field	2.7	0.3	0.0 - 1.3	0.4	0.0 - 1.6	0.0	N/A
Maintained lawn	1.8	3.4	0.5 - 6.3	0.0	N/A	0.0	N/A
Agriculture	3.9	0.0	N/A	0.0	N/A	0.0	N/A
Unvegetated	0.4	0.3	0.0 - 1.2	0.0	N/A	0.0	N/A
Residential	0.3	0.0	N/A	0.0	N/A	0.0	N/A

[a]Includes developed forest cover type

Table 24. Availability and use of cover types by white-tailed deer that had greater than 50% home range area within Valley Forge National Historical Park during 1997, 1998, and 1999 combined.

		Females		Males	
Cover type	Available (%)	Locations (%)	95% CI	Locations (%)	95% CI
Deciduous forest[a]	47.8	42.8	40.6 - 44.9	47.0	41.2 - 52.7
Conifer forest	2.8	2.3	1.6 - 2.9	2.5	0.7 - 4.3
Meadow	40.1	50.3	48.2 - 52.4	48.21	42.4 - 53.9
Field	2.7	3.1	2.4 - 3.9	0.4	0.0 - 1.0
Maintained lawn	1.8	0.8	0.4 -1.2	1.8	0.3 - 3.3
Agriculture	3.9	0.0	N/A	0.0	N/A
Unvegetated	0.4	0.2	0.0 - 0.4	0.2	0.0 - 0.7
Residential	0.3	0.4	0.2 - 0.7	0.0	N/A

[a]Includes developed forest cover type

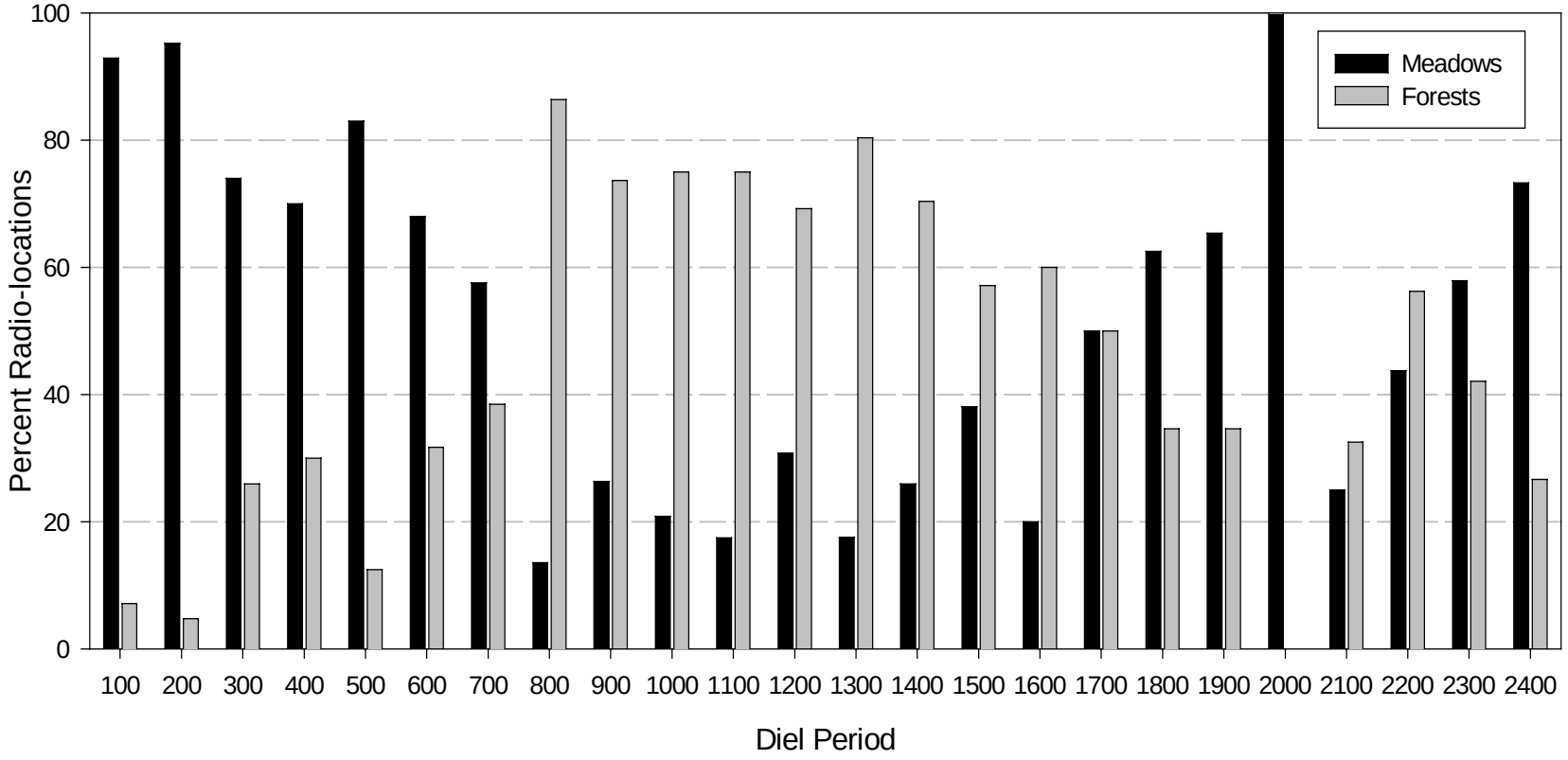

Figure 11. Diel use of meadow and forest cover types by male white-tailed deer that had greater than 50% home range area within Valley Forge National Historical Park during 1997, 1998, and 1999 combined.

Cover-type Use Outside the Park

The area adjacent to the park boundary was dominated by deciduous forest components (developed and undeveloped) and high-density residential areas (Table 25). During all years combined, females with greater than 50% home range area outside the park did not use cover types in proportion to their availability ($\chi^2_7 = 174.6$, $P < 0.001$) (Table 25). Females used deciduous forest and agricultural cover-types more than expected based on availability and used residential areas less than expected. This pattern of cover-type use by females was generally consistent among years 1997 ($\chi^2_7 = 109.9$, $P < 0.001$), 1998 ($\chi^2_7 = 69.5$, $P < 0.001$), and 1999 ($\chi^2_7 = 52.9$, $P < 0.001$) (Table 26). Female deer used deciduous forest more than expected during 1998 and 1999 and in proportion to availability during 1997. Use of agricultural cover types was more than expected during 1997 and 1998, but was used in proportion to availability during 1999. Residential areas beyond the park boundary were used less than expected by female deer during all years (Table 26).

During all years, male deer that had greater than 50% of the home range area outside the park did not use cover types in proportion to their availability ($\chi^2_7 = 19.7$, $P = 0.001$). Males used residential areas beyond the park boundary less than expected and used all other types in proportion to their availability. The number of male locations beyond the park boundary was limited and was insufficient to compute annual estimates of cover-type use.

Landscape Use

Composite (over deer and years (1997, 1998, and 1999)) landscape utilization distributions of radio-marked deer that had greater than 50% of the home range area within the park indicated high use in the central to the southwestern portion of VAFO (Figure 12). Patterns of landscape use within years 1997 (Figure 13), 1998 (Figure 14) and 1999 (Figure 15) were similar. The utilization distributions (Figures 12, 13, 14, and

Table 25. Availability and use of cover types by white-tailed deer that had greater than 50% home range area on private lands adjacent to Valley Forge National Historical Park during 1997, 1998, and 1999 combined.

		Females		Males	
Cover type	Available (%)	Locations (%)	95% CI	Locations (%)	95% CI
Deciduous forest	19.8	25.1	20.8 - 29.3	23.2	12.7 - 33.7
Developed forest	29.6	30.5	26.9 - 35.0	34.8	22.9 - 46.7
Conifer forest	0.3	0.4	0.0 - 0.9	0.0	N/A
Meadow	0.0	N/A	N/A	N/A	N/A
Field	8.9	11.3	8.2 - 14.3	17.0	7.6 - 26.3
Maintained lawn	2.5	3.2	1.5 - 4.9	2.7	0.0 - 6.7
Agriculture	5.8	13.7	10.3 - 17.1	7.1	0.7 - 13.6
Unvegetated	0.8	1.0	0.1 - 1.9	0.0	N/A
Residential	32.2	14.9	11.5 - 18.4	15.2	6.2 - 24.1

Table 26. Availability and use of cover types by female white-tailed deer that had greater than 50% home range area on private lands outside the boundary of Valley Forge National Historical Park during 1997, 1998, and 1999.

		1997		1998		1999	
Cover type	Available (%)	Locations (%)	95% CI	Locations (%)	95% CI	Locations (%)	95% CI
Deciduous forest	19.8	26.2	19.0 - 33.4	29.9	22.7 - 37.0	28.9	20.2 - 37.6
Developed forest	29.6	35.1	27.3 - 43.0	21.8	15.3 - 28.2	25.0	16.7 - 33.3
Conifer forest	0.3	0.4	0.0 - 1.3	0.7	0.0 - 1.9	0.0	N/A
Meadow	0.0	N/A	N/A	N/A	N/A	N/A	N/A
Field	8.9	11.1	5.6 - 16.3	11.4	6.4 - 16.3	11.3	5.2 - 17.3
Maintained lawn	2.5	2.9	0.1 - 5.6	3.6	0.7 - 6.5	2.9	0.0 - 6.2
Agriculture	5.8	15.8	9.8 - 21.8	13.0	7.7 - 18.3	11.8	5.6 - 17.9
Unvegetated	0.8	0.0	N/A	0.3	0.0 - 1.2	3.4	0.0 - 6.9
Residential	32.2	8.6	4.0 - 13.2	19.5	13.3 - 25.7	16.7	9.5 - 23.8

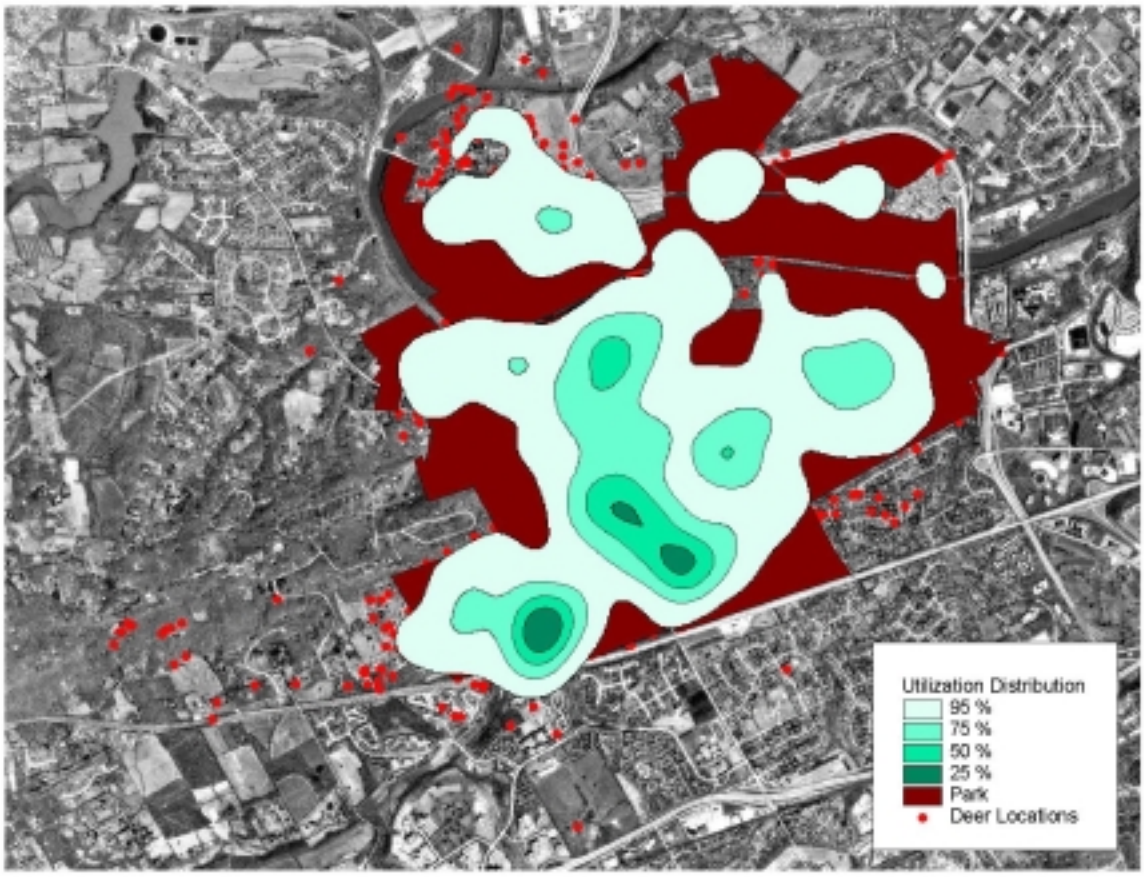

Figure 12. Landscape use by radio-marked white-tailed deer that had greater than 50% home range area within Valley Forge National Historical Park composited over 1997, 1998, and 1999.

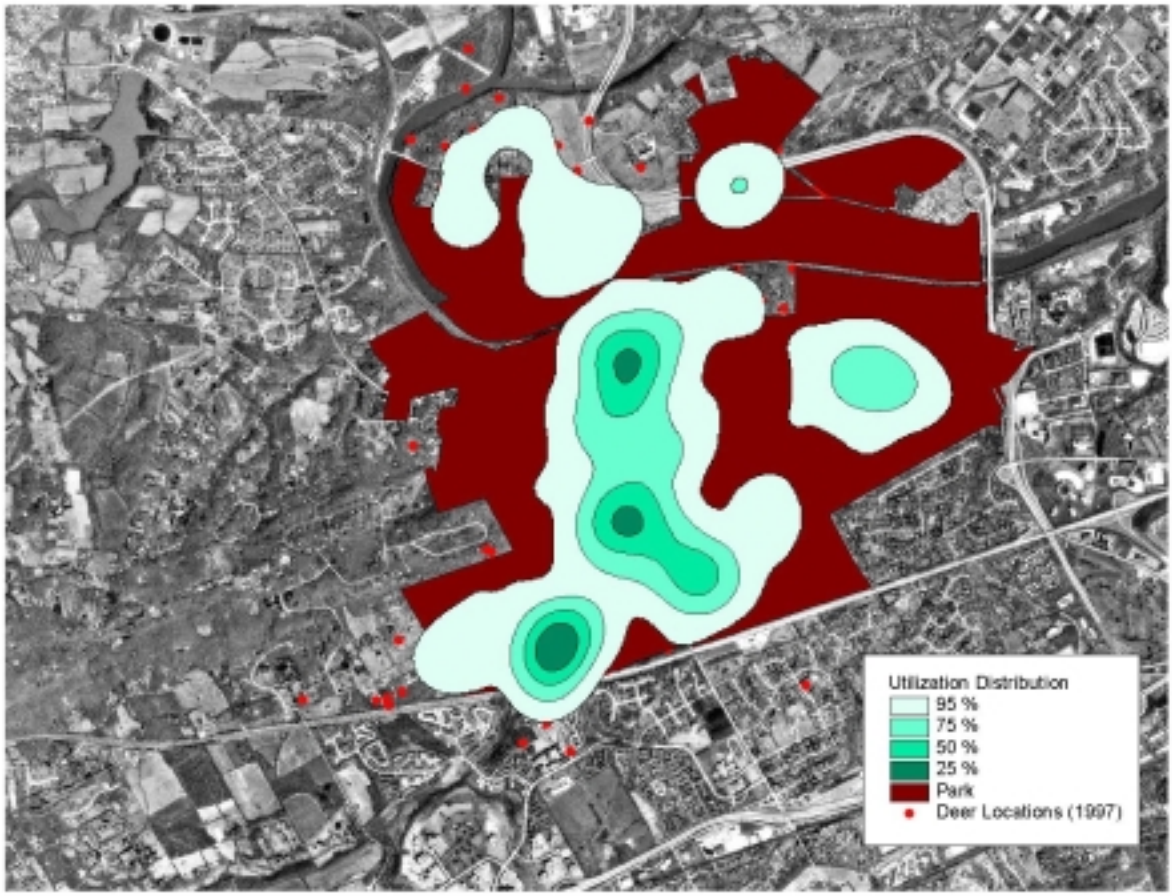

Figure 13. Landscape use by radio-marked white-tailed deer that had greater than 50% home range area within Valley Forge National Historical Park, 1997.

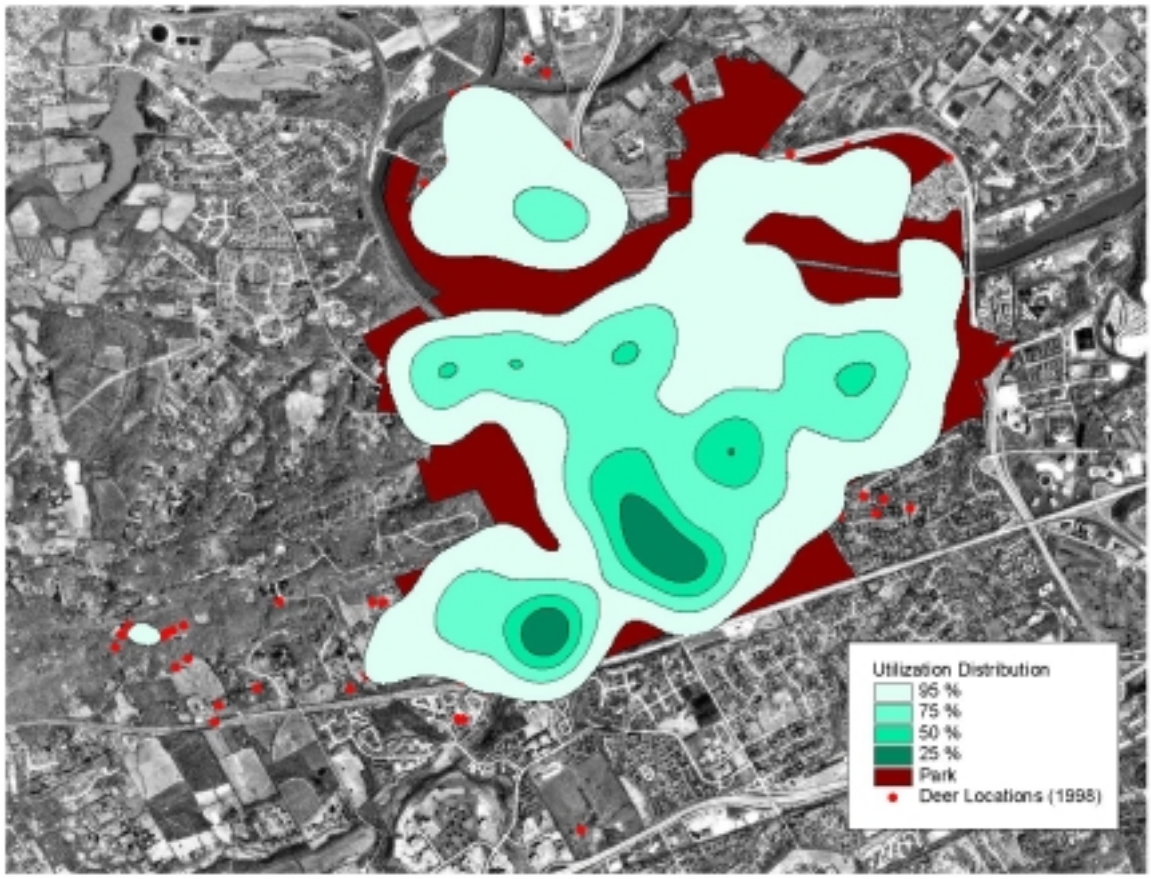

Figure 14. Landscape use by radio-marked white-tailed deer that had greater than 50% home range area within Valley Forge National Historical Park, 1998.

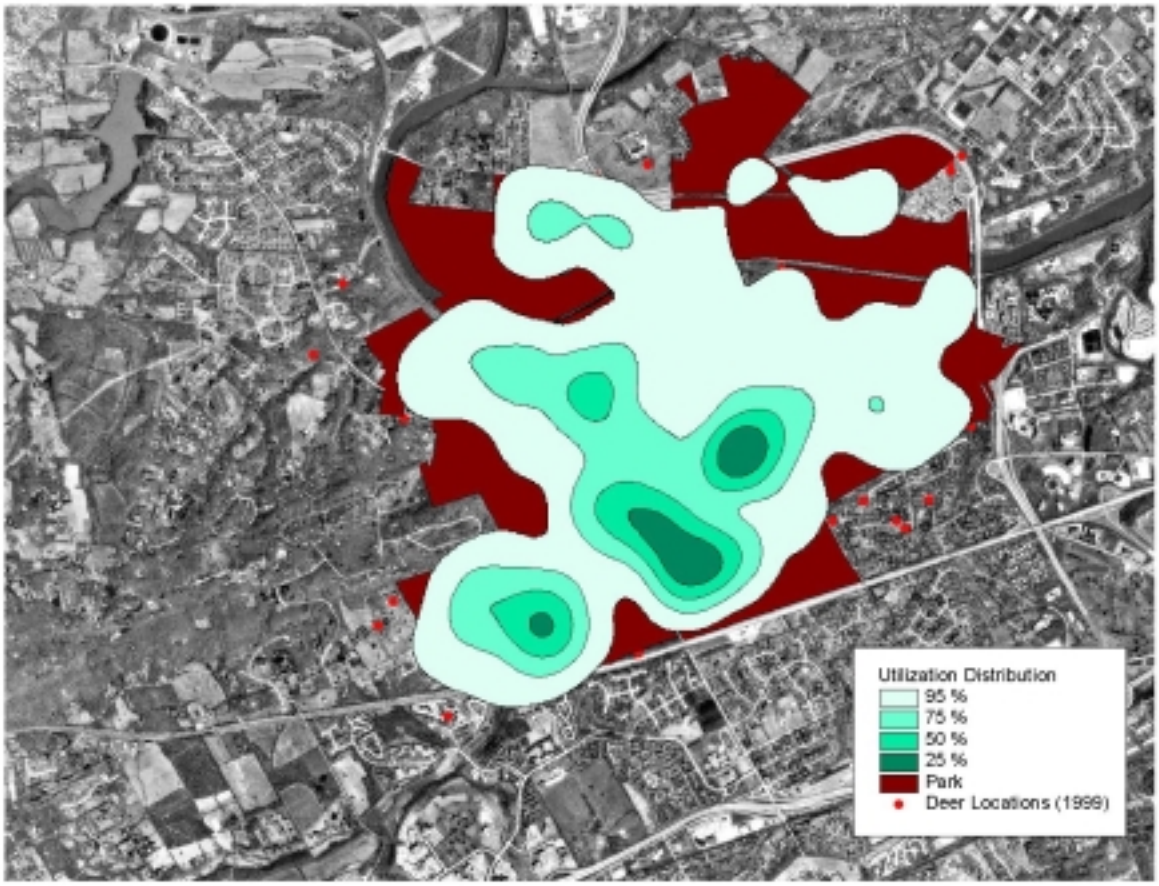

Figure 15. Landscape use by radio-marked white-tailed deer that had greater than 50% home range area within Valley Forge National Historical Park, 1999.

15) represent, in a probabilistic sense, the most likely areas of occurrence of white-tailed deer. Consistently, the southwestern portion of the park was an area of high probability of occurrence.

In the west-southwestern corner of the park, daily movements by deer occurred primarily from Sterling's residence and the Turnpike to the housing development west of the park, where deer would spend the nocturnal period. In the western portion of the park, south of the river, there was very little movement between the park and private property. On the north side of the park and north of the river there were nocturnal movements of deer into the housing development; most movement was <200m from the park boundary. Deer that occupied the area adjacent to the agricultural fields (St. Gabriel's) foraged in and around those fields and spent the diurnal period in the park woodlot.

There was little to no movement of deer into the mobile home development on the northeastern and eastern boundary of the park. There was, primarily nocturnal, movement of deer into the housing development on the southeastern portion of the park. The Turnpike was a significant barrier to deer along the southern park boundary. But, deer did cross the Turnpike near the southwestern boundary.

Mortalities

Of the 120 deer that were captured and marked during 1997, 1998, and 1999, a total of 39 mortalities were observed (Table 27). Vehicle collisions were the most common cause of mortality and accounted for 69 percent (27 of 39) of all mortalities (Table 28). Legal harvest by archers on private property accounted for 18% (7 of 39) of mortalities observed, whereas illegal shooting accounted for at least 3 mortalities (8%). Upon completion of the project, 2 mortalities were attributed to unknown causes, and 2 deer were classified as missing.

Table 27. Mortalities of marked white-tailed deer recorded within Valley Forge National Historical Park and surrounding private lands during 1997, 1998, and 1999.

Deer ID	Capture date	Sex	Age	Capture Location	Date died	Cause
3	02/13/1997	Male	Adult	Park	12/15/1997	Vehicle
4	02/18/1997	Female	Adult	Park	10/18/1999	Harvest
5	02/18/1997	Female	Juvenile	Park	03/24/1997	Vehicle
7	02/19/1997	Female	Juvenile	Private	10/04/1997	Harvest
9	02/19/1997	Female	Adult	Park	02/23/1997	Unknown
12	02/22/1997	Female	Adult	Park	01/15/1998	Vehicle
13	02/23/1997	Female	Adult	Park	02/06/1998	Vehicle
14	02/23/1997	Female	Adult	Park	07/12/1999	Vehicle
17	02/24/1997	Female	Adult	Park	12/15/1998	Illegal
18	02/25/1997	Female	Juvenile	Park	07/01/1997	Vehicle
19	02/26/1997	Female	Juvenile	Park	12/23/1997	Illegal
21	03/04/1997	Female	Adult	Park	12/01/1997	Vehicle
23	03/04/1997	Female	Adult	Park	07/03/1997	Vehicle
25	03/05/1997	Female	Adult	Private	10/03/1999	Harvest
28	03/11/1997	Female	Adult	Private	10/03/1999	Harvest
29	03/11/1997	Female	Adult	Park	04/30/1998	Vehicle
31	03/12/1997	Male	Juvenile	Park	10/28/1997	Harvest
32	03/12/1997	Female	Adult	Private	10/28/1997	Harvest
36	03/12/1997	Female	Adult	Private	07/08/1997	Unknown
42	03/22/1997	Female	Adult	Park	04/04/1997	Vehicle
43	03/23/1997	Female	Adult	Private	10/30/1997	Harvest
44	03/24/1997	Female	Adult	Private	04/14/1997	Illegal
50	01/31/1998	Female	Adult	Park	09/11/1998	Vehicle
54	02/06/1998	Female	Adult	Park	06/24/1999	Vehicle
57	02/07/1998	Female	Adult	Private	07/27/1998	Vehicle
60	02/08/1998	Female	Adult	Private	04/04/1999	Vehicle
61	02/08/1998	Female	Adult	Park	11/10/1999	Vehicle
73	02/14/1998	Female	Adult	Private	09/07/1998	Vehicle
77	02/25/1998	Female	Adult	Park	07/02/1999	Vehicle
83	02/28/1998	Female	Adult	Private	05/28/1999	Vehicle
87	03/01/1998	Female	Adult	Park	03/01/1999	Vehicle
88	03/10/1998	Female	Adult	Park	02/14/1999	Vehicle
92	03/11/1998	Female	Adult	Park	07/16/1999	Vehicle
93	03/12/1998	Female	Adult	Park	09/11/1998	Vehicle
100	03/20/1998	Female	Adult	Private	04/03/1998	Vehicle
114	03/08/1999	Female	Adult	Private	05/02/1999	Vehicle
115	03/08/1999	Female	Adult	Park	05/12/1999	Vehicle
118	04/01/1999	Female	Adult	Private	08/12/1999	Vehicle
120	04/01/1999	Female	Adult	Private	04/12/1999	Vehicle

Table 28. Cause-specific mortality of marked white-tailed deer within Valley Forge National Historical Park and surrounding private lands during 1997, 1998, and 1999.

	1997		1998		1999		All Years	
Cause	n	%	n	%	n	%	n	%
Vehicle collision	6	42.9	8	88.9	13	81.3	27	69.2
Legal harvest	4	28.6	0	0.0	3	18.8	7	17.9
Illegal harvest	2	14.3	1	11.1	0	0.0	3	7.7
Unknown	2	14.3	0	0.0	0	0.0	2	5.1
Total	14	100.0	9	100.0	16	100.0	39	100.0

The percentage of the total marked sample that died due to vehicle collisions was consistent among years and ranged from 9.8% during 1998 to 13.8% during 1999 ($\bar{x}$ = 12.2%, SD = 2.4%) (Table 29). The percent of the marked sample that died due to legal harvest (primarily archery hunters) was greatest during 1997 (8.9%); no legal harvest of marked deer occurred during 1998. Illegal harvest was detected during 1997 (n = 2) and 1998 (n = 1). The annual percent loss for all tagged deer within the park and surrounding private lands ranged from 10.7% to 31.1% ($\bar{x}$ = 19.6%, SD = 10.4%).

Annual mortality (percent loss) of marked deer was greatest during 1997 when 31% of the marked sample died. Deer that were marked during 1997 and survived the first year of the project experienced increased survival during subsequent years (Table 30). This pattern was not true for deer marked during 1998; this sample experienced greater annual percent loss during 1999 than during 1998. If annual marked samples were considered independent, average annual loss of the marked sample was 17.3% (SD = 7.7%).

Deer that were marked beyond the park boundary experienced higher annual mortality than deer marked within the park during all years (Table 31). Percent annual mortality due to vehicle collisions was greater for deer captured within the park than deer captured beyond the boundary of the park during 1997, but not during subsequent years. Percent annual mortality due to legal harvest was greater for deer captured beyond the boundary of the park during 1997 and 1999; no legal harvest of marked deer occurred during 1998.

A limited sample of males (8 during 1997, 8 during 1998, and 3 during 1999) and limited ear-tag transmitter life precluded intersexual comparisons of cause-specific mortality. Two of 8 males that were marked during 1997 died during 1997. No male mortalities were observed during 1998 and 1999. Similarly, age-specific comparisons were limited by a relatively small sample of juveniles (n = 10) that were marked during 1997. One of 6 marked juvenile males died during 1997, whereas all four of the marked juvenile females died during 1997.

Table 29. Cause-specific mortality (n) of the annual sample of marked (N) white-tailed deer within Valley Forge National Historical Park and surrounding private lands during 1997, 1998, and 1999.

Cause	1997 (N=45)		1998 (N=84)		1999 (N=94)		Overall Mortality (%)	
	n	%	n	%	n	%	$\bar{x}$	SD
Vehicle collision	6	13.3	8	9.5	13	13.8	12.2	2.4
Legal harvest	4	8.9	0	0.0	3	3.2	4.0	4.5
Illegal harvest	2	4.4	1	1.2	0	0.0	1.9	2.3
Unknown	2	4.4	0	0.0	0	0.0	1.5	2.6
Total	14	31.1	9	10.7	16	17.0	19.6	10.4

Table 30. Mortality (n) observed each year from each annual sample of marked white-tailed deer within Valley Forge National Historical Park and surrounding private lands during 1997, 1998, and 1999

Year marked	Marked	1997		1998		1999	
		n	%	n	%	n	%
1997	45	14	31.1	4	12.9	4	14.8
1998	55			5	9.1	8	16.0
1999	20					4	20.0

Table 31. Cause-specific mortality (n) of available marked white-tailed deer (N) that were captured within Valley Forge National Historical Park (Park) and surrounding private lands (Private) during 1997, 1998, and 1999.

Cause	1997				1998				1999			
	Park (N=36)		Private (N=9)		Park (N=62)		Private (N=22)		Park (N=67)		Private (N=27)	
	n	%	n	%	n	%	n	%	n	%	n	%
Vehicle collision	6	16.7	0	0.0	5	8.1	3	13.6	8	11.9	5	18.5
Legal harvest	1	2.8	3	33.3	0	0.0	0	0.0	1	1.5	2	7.4
Illegal harvest	1	2.8	1	11.1	1	1.6	0	0.0	0	0.0	0	0.0
Unknown	1	2.8	1	11.1	0	0.0	0	0.0	0	0.0	0	0.0
Total	9	25.0	5	55.6	6	9.7	3	13.6	9	13.4	7	25.9

Discussion

North America supports 28.5 million white-tailed deer (Crete and Daigle 1999). In 2000, Pennsylvania supported 1.5 million white-tailed deer (Rosenberry 2001) at an average density of 12.8 deer/km^2 (33.2 deer/mile^2). During 1997 to 1999, Valley Forge National Historical Park supported annually 900 deer at a density of 70 deer/km^2 (181 deer/mile^2). During 1990 to 1993, white-tailed deer density at Gettysburg National Military Park, PA ranged from 37 to 53 deer/km^2 (95-136 deer/mile^2). At Letterkenny Army Depot, near Chambersburg, PA, a 4,856-ha area enclosed with chain-link fence supported an estimated 58 deer/km^2 (150 deer/mile^2) during 1992 to 1994. These estimated densities were 7 and 12 times higher, respectively, than the densities in the corresponding surrounding counties (Palmer et al. 1997). Since the above timeframe, Gettysburg National Military Park initiated a sharp-shooter deer culling operation and Letterkenny Army Depot, which had regulated deer hunting, has intensified the hunting pressure.

Captured deer at VAFO appeared to be typical white-tailed deer in terms of gross appearance, condition, and size, as compared to other deer examined in Pennsylvania (Palmer et al. 1997). During 1997, the majority of the deer that we captured were adult females, however, we also captured and marked males and young deer to increase the sample of marked deer. Thereafter, we captured and marked primarily adult females.

Ideally, a complete count (a census) of white-tailed deer would be preferred (Caughley 1977, Thompson et al. 1998). But a census of free-ranging deer is not feasible. Therefore, we exploited a sampling strategy to estimate abundance. The strategy consisted of several components: 1) partition VAFO and some surrounding private land into compartments to count deer (a logistical constraint), 2) mark a representative sample of deer, 3) know their locations (telemetry and visually), 4) conduct replicate counts of deer within compartments, and 5) adjust these counts by a sighting index (marked deer seen/marked deer available to be seen) that provided an estimate of white-tailed deer abundance. Please see Storm et al. (1992) and Tzilkowski and Storm

(1993) for details. Valley Forge National Historical Park was bounded, accessible, and of relatively uniform landscape types; therefore, we were able to develop accurate and precise abundance estimates.

We estimated the 1998 and 1999 annual rates of increase for white-tailed deer as 18% and 11% respectively, which are consistent with reported rates for George Reserve, MI (McCullough 1982), Remington Farms, MD (Lancia, et al. 1988), and Gettysburg, PA (Storm et al. 1992).

White-tailed deer have been common and abundant in Pennsylvania, including VAFO, for many years (decades). White-tailed deer range expansion is thought to be driven primarily by dispersal of yearling male deer rather than home range expansion (Nelson and Mech 1999). This process is important in the establishment of deer in an unoccupied area. This process is ongoing, but its primary effect was experienced years ago at VAFO. Currently, natal dispersal tends to shuffle yearlings (Rosenberry et al. 1999) from a relatively high-density area to areas of lower density. The most widely accepted hypothesis is that dispersal evolved as a means to reduce inbreeding (Holzenbein and Marchinton 1992). A current model of home range dynamics of white-tailed deer suggests that a population expands spatially through slow incremental proliferation by progeny from matriarchal home ranges (Porter et al. 1991). Our primary focus in terms of use of space was adult females.

Studies concerning the use of space by white-tailed deer in various habitats, such as forests, range, and agricultural settings, are numerous (e.g., Rongstad and Tester 1969, Sparrowe and Springer 1970, Storm et al. 1995, and Tierson et al. 1985). There have been fewer descriptions of white-tailed deer movements, home range, or habitat use in the urban - suburban setting (Cornicelli 1992, Grund 1998, and Kilpatrick and Spohr 2000a).

White-tailed deer home range varies as a function of geographical area, habitat, deer density, age, and sex (Hawkins and Klimstra 1970). Home range must be large enough to meet the needs for life and reproduction yet small enough to gain, through familiarity, survival advantage (Marchinton and Hirth 1984). In forested settings, white-tailed deer

home range varies from 59 ha (146 acres) in the southern forests of Georgia (Marshall and Whittington 1969) to 500 ha (1,235 acres) in the northern forests of Wisconsin (Alverson et al. 1988) and Quebec (Lesage et al. 2000).

Home range is a concept that lacks a perfect estimator (White and Garrott 1990). Many estimators have been proposed including the minimum convex polygon (Mohr 1947) and the adaptive kernel (Worton 1987). The minimum convex polygon is conceptually simple, widely applied, and frequently reported. Peripheral locations are joined by a connecting rule, a polygon with all internal angles <180 degrees, which yields the smallest area that contains all location points (Worton 1987). The adaptive kernel estimator is statistically based, and less frequently applied or reported. The adaptive kernel combines the kernel method, a nonparametric statistical method for smoothing a sample of two-dimensional locations, and the nearest neighbor (location) approach. Please see Worton (1987, 1989) for details. The strength of the adaptive kernel is primarily if the home range consists of disjoint areas, which was not the case at VAFO. We presented both home-range estimates, which were correlated, but focused on the minimum convex polygon.

Cornicelli (1992) and Grund (1998) reported on female white-tailed deer movements and use of space in urban and suburban landscapes of southern Illinois and Bloomington, Minnesota, respectively, as cited by Kilpatrick and Spohr (2000a). Cornicelli (1992) concluded deer avoided residential developments during all seasons. Grund (1998) concluded deer avoided residential areas, except during winter.

Cornicelli (1992), Grund (1998), and Kilpatrick and Spohr (2000a) reported annual average female home range areas of 25.6, 87.5, and 43 ha, respectively, that were considerably smaller than those reported for forested or agricultural-dominated landscapes. Female white-tailed deer in Valley Forge National Historical Park and environs had an average annual home range area of 100.7 ha (249 acres) based on the minimum convex polygon method and 94.6 ha (234 acres) based on the 95% adaptive kernel method. These home range areas were larger than reported for the above estimates for urban—suburban landscapes but smaller than those reported for a

Connecticut suburb (158 ha) (Swihart, 1995), a Nebraska agricultural setting (170 ha) (VerCauteren and Hygnstrom, 1998), and Gettysburg National Military Park (161 ha) (Storm et al., 1995).

In Connecticut (Kilpatrick and Spohr 2000a, 2000b), 25 female white-tailed deer were radio-marked within two residential areas comprising 187 ha. One area was 81 ha, containing 104 house lots, $\leq$ 0.6 ha each, interspersed with 42 ha of open space (hardwoods, old fields, and marsh). The adjacent area was 106 ha, containing 600 house lots, $\leq$ 0.2 ha each, and 43 ha of open space (hardwoods and salt marsh). The deer had overlapping home ranges that averaged 43 ha. Geographic features (large water bodies) and manmade structures (heavily used railroad system) formed portions of home range boundaries for many deer. Kilpatrick and Spohr (2000a, 2000b) concluded habitat fragmentation and the insular characteristics of the suburban landscape restricted deer activity, home range size, spatial arrangement, and configuration.

At Valley Forge National Historical Park, median home range of adult females that had greater than 50 percent of their home range within the park did not differ from adult females that had less than 50 percent of the home range within the park. The same was true for adult males. Regardless of the landscape elements contained within the home range, the median areas were not different. Furthermore, artificial boundaries had little influence on home range area, arrangement, or configuration. However, there were home ranges that appeared to be influenced by geographic boundaries (river) or manmade structures (major highway).

Cover type composition varied within and outside the park. Therefore, individual deer home ranges contained different proportions of the various cover types. Female deer that had greater than 50 percent of the home range within the park used the meadow cover type more than expected, primarily between 2200 – 0600 hours, and deciduous forest less than expected, primarily during diurnal periods. The deciduous forest areas provided daytime cover and the meadows provided food. Male deer used residential areas less than expected and females used residential areas in proportion to its

relatively low (< 0.5%) availability. For deer that had greater than 50 percent of the home range outside the park, females used deciduous forest and agricultural cover types more than expected and residential areas less than expected. The few marked males avoided residential areas.

Avoidance of residential areas was consistent with results reported by Cornicelli (1992) and Grund (1998). However, Grund (1998) reported deer did not avoid residential areas in winter. Kilpatrick and Spohr (2000a) concluded all marked deer were residents of the human-residential areas, and shifted core areas of home range closer to houses during winter, primarily to feed from bird feeders.

Average distance traveled beyond the VAFO boundary was 122 m (1,094 m maximum) for female white-tailed deer that had greater than 50 percent of home range within the park, with most of these movements occurring during 1200-1800 hours, versus 404 m (1,985 m maximum) for females that had greater than 50% of home range outside the park, with most of these movements occurring during 1800-2400 hours and the least during 1200-1800 hours. Adult females that were captured within the park were subsequently located primarily within the park. Adult females captured outside the park were subsequently located primarily outside the park. However, the white-tailed deer ignored human-construed boundaries among properties (public and private). In Connecticut, Kilpatrick and Spohr (2000b) documented deer, which had the smallest reported home ranges (43 ha), traveling as far as 860 m from patches of cover into residential developments which comprised 34% of annual home ranges.

VAFO deer experienced relatively high average annual survival (83%). DePerno et al. (2000) reported adult female annual survival as 10% for a declining white-tailed deer population. However, typical annual survival rates for adult females vary from 65-85% (Gavin et al. 1984, Fuller 1990, Nixon et al. 1991, Whitlaw et al. 1998).

In terms of herbivores and their environment, Caughley (1981:7-9) outlined four classes of overpopulation that have been either misrepresented or misconstrued as herbivores (e.g. white-tailed deer) being out-of-balance with their food resource-- exceeding ecological carrying capacity. These classes are:

1. The animals threaten human life or livelihood.
2. The animals depress the densities of favored species.
3. The animals are too numerous for their own good.
4. The system of plants and animals is off its equilibrium.

The terminology that is in vogue today with respect to herbivores and their environment is environmental or cultural carrying capacity. Cultural carrying capacity encompasses one or some combination of the above items one through three. Item four has little meaning in such a human-modified environment such as VAFO. VAFO supported one of the highest reported white-tailed deer densities in North America and survival was high. The potential for continued growth is also high.

Muth and Jamison (2000:850) concluded that if wildlife (e.g. white-tailed deer) overabundance results in escalating conflict between wildlife and people, then wildlife management will shift from conservation to pest management mode. This shift will not only potentially weaken the support the American public has traditionally invested in wildlife conservation but also diminish..."the respect, wonder, and awe with which many people in modern society presently regard wildlife."

Conclusions

In addition to documenting white-tailed deer movement, home ranges, and habitat use estimates, we estimated the annual rate of population growth as 18% for 1998 and 11% for 1999, at Valley Forge National Historical Park. White-tailed deer density was among the highest (70 deer/km^2; 181 deer/mile^2) of any reported area with free-roaming deer in North America. Given the high density, relatively low mortality, and high productivity, as expressed in growth rates, the potential for continued population growth of white-tailed deer at Valley Forge National Historical Park is high.

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Appendix. Radio-telemetry obtained locations of radio-equipped white-tailed deer within Valley Forge National Historical Park and surrounding lands during 1997, 1998, and 1999.

Maps for the following deer ID numbers (see Tables 4, 5, and 6) were not included in this appendix due to a paucity of location data (transmitter failure, mortality, etc.).

5	53	107
8	65	108
9	66	109
30	74	110
33	79	112
34	92	114
36	100	115
37	102	116
38	103	117
41	104	118
42	105	119
44	106	120

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